CHAPTER 6

PRIME MOVERS, PUMPS, AND AIR COMPRESSORS

LEARNING OBJECTIVE: *Identify types and uses of prime movers, pumps, and air compressors; identify procedures required in preventive maintenance and maintenance on pumps and air compressors.*

Because of the many types of prime movers, pumps, and air compressors used by Navy units, the information presented on operating procedures and maintenance requirements in this chapter is brief and general. The emphasis is on fundamental operating principles, parts, and maintenance of prime movers, pumps, and air compressors, and operating problems you may experience.

Local commands develop specific operator maintenance schedules, logs, and reports. Each local command also maintains a file of manufacturer's instructions, parts lists, drawings, and diagrams for all equipment installed or used in that command. Taken together, these maintenance schedules, manufacturer's instructions, and so on, provide you with detailed information on operating procedures and maintenance requirements. Always get to know these guides before attempting to operate and maintain the equipment for which you are responsible.

There are several important Navy training publications of which you need to be aware. Although these books are described as basic texts, the information they contain can help you better understand the equipment covered in this chapter. To learn more about the operating principles and construction of electric motors, you should obtain a copy of each of the following TRAMANs:

- Module 5, *Introduction to Generators and Motors,* Navy Electricity and Electronics Training Series (NEETS), NAVEDTRA B72-05-00-96.
- *Basic Machines,* NAVEDTRA 12199, explains the operating principles and construction of internal combustion engines.
- *Fluid Power,* NAVEDTRA 12966, discusses fluid physics, construction, and operating principles of pumps and air compressors, valves, packing, pressure gauges, and fluid piping, tubing, and temperature.

PRIME MOVERS

LEARNING OBJECTIVE: *Identify the basic types, the operation, and the maintenance of prime movers.*

Prime movers are often called "driving equipment" because they are the primary source of mechanical energy or power. The mechanical energy produced by the prime mover is transmitted to another machine or mechanism, such as a pump or air compressor, to do some form of useful work. The mechanism, or linkage, that transmits the mechanical power developed by the prime mover is called the drive.

Electric motors and internal combustion engines are commonly used as prime movers. For this reason, this chapter briefly covers electric prime movers, gasoline-operated prime movers, and diesel-operated prime movers.

ELECTRIC MOTORS

As prime movers, electric motors receive electrical energy from some external source and transform it into the mechanical energy needed to produce work. Electric motors are either direct current (dc) or alternating current (ac). Because most of the electrical power generating systems that Seabees come in contact with produces alternating current, only the ac motor will be discussed.

Induction AC Motor

Of the various types of ac motors available, you will work primarily with the rotating-field INDUCTION ac motor. The popularity of this motor is due largely to its reliability and simplicity of construction. The basic induction motor has two main assemblies or components-a ROTOR and a STATOR, as shown in figure 6-1. The mechanical rotation of the rotor is produced through the principle of electromagnetic induction. Alternating current flows through the stator (a circular assembly of stationary coils or windings) which surrounds the rotor. The alternating current flow in the stator produces a constantly rotating magnetic field. This magnetic field induces a current flow in the conductors of the rotor (a cylindrical or drumlike assembly of copper bars mounted on a shaft). The induced current in the rotor then produces a magnetic field of its own. The magnetic field of the rotor is produced so it opposes the magnetic field of the stator; that is, the two fields repel each other. This continuous repulsion of the rotor field by the stator field results in a continuous rotation of the rotor assembly around its axis or shaft. Thus electrical rotation (in the stator) is transformed into mechanical rotation (in the rotor).

The rotational speed of the stator field remains constant unless the frequency of the electrical power source varies. The rotational speed of the rotor is also constant and is more or less independent of the workload imposed on it. This is not to say, however, that an induction motor cannot be overloaded. Under heavy or excessive loads, the motor tends to draw more current to maintain speed; this can result in over-heating and burned-out windings.

Induction motors are usually named by the method used for starting the motor. Two fairly common types of induction motors, classified in this manner, are the SPLIT-PHASE MOTOR and the CAPACITOR-START MOTOR. Split-phase induction motors are designed to operate on single-phase current. Induction motors require two or more out-of-time-phase currents to produce the continuously rotating magnetic field in the stator. For this reason, induction motors that must run on a single-phase power supply are provided with split-phase windings that make two phases of the single-phase current. Split-phase motors can be used to drive a variety of equipment, such as washing machines, oil burners, small pumps, and blowers. The capacitor-start induction motor is a variation of the split-phase motor, but it has a high capacity, electrolytic capacitor. The primary function of this device is the storage of electricity to provide more power during the start.

There are a number of mechanical modifications to induction motors. The most important are as follows: (1) the splashproof motor; (2) the totally enclosed, fan-cooled motor; and (3) the explosionproof motor.

The splashproof motor is constructed so dripping or splashing liquids cannot enter the motor. The motor is self-ventilated; but, since moisture-saturated air may be circulated through the motor, the windings are made moisture-resistant. Motors of this type are most often used to drive pumps and other machinery where the moisture content of the air is high.

The totally enclosed, fan-cooled motor has totally enclosed windings and rotor. Cooling air is circulated over the enclosure to remove heat. This motor is used in locations where the surrounding air may contain a high proportion of dust, as in a carpenter shop.

The explosionproof motor is similar to the totally enclosed fan-cooled motor; but, it is constructed to prevent any explosion within the motor from igniting combustible gases or dust in the surrounding air. This

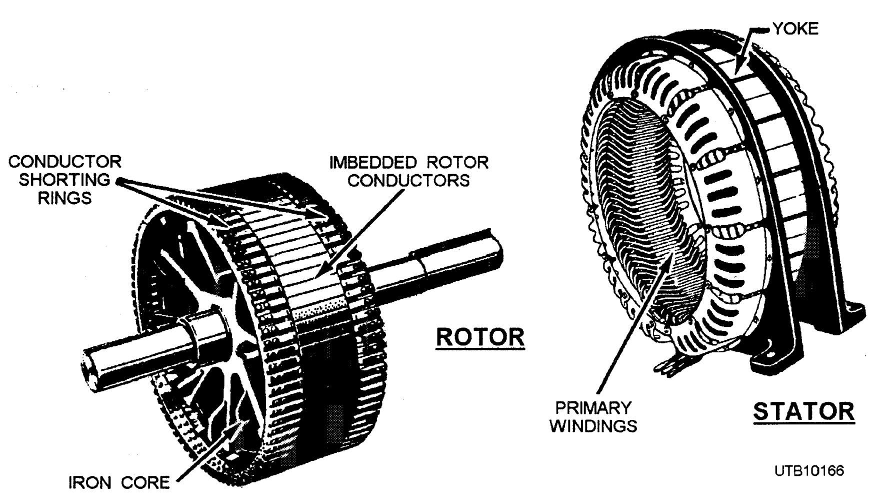

Figure 6-1.—Rotor and stator assemblies of an induction motor.

motor is extensively used in sewage treatment plants and at other locations to ensure safe operation.

The operation and operator maintenance of electric motors has four main aspects-(1) lubrication of moving or rotating parts, (2) proper alignment of drives, (3) safety, and (4) cleanliness of windings and rotors. Pay careful attention to each of these factors to ensure motor efficiency and, in many cases, to prevent motor breakdown.

LUBRICATION. —Electric motors are fitted with bearings which reduce friction. The types of bearings most often used are sleeve bearings, roller bearings, or ball bearings. For these bearings to remove the heat generated by friction, they must be properly lubricated. The lubricant used is usually either grease or oil.

Some motors are equipped with ball bearings permanently lubricated or packed with grease when the motor is assembled at the factory. These bearings are usually covered with a nameplate that reads-Do Not Lubricate. Most electric motor bearings, however, must be lubricated at frequent intervals. In such cases, the lubricant is fed to the bearings through a pressure fitting or grease nipple from a hand-operated grease gun. Or, the lubricant may be metered to the bearings from a grease or oil cup, which must be periodically turned or screwed down by hand to keep the bearings supplied with lubricant (fig. 6-2).

Some rotating shafts are fitted with sleeve bearings that usually are soft brass cylinders that fit around the machine-shaft journal like a sleeve. In some installations, the lubricating oil is circulated through the sleeve bearings under pressure. Some sleeve bearings, however, may be lubricated by means of an oil ring, or rings, as shown in figure 6-3. The weight of the ring hanging on the journal is enough to cause it to revolve, as the shaft revolves. As the oil ring rotates, it dips into an oil reservoir directly beneath the shaft journal. The oil picked up by the ring is then diffused along the shaft, between the shaft journal and sleeve bearing. Proper lubrication of ring-oiled sleeve bearings depends on maintaining a sufficient oil level in the reservoir. For this reason, most sleeve bearings have oil filler gauges or overflow fittings installed to aid the operator in maintaining the oil at a proper level.

When the electric motor is in operation, the operator is required to make frequent checks and inspections for proper lubrication of bearings and for overheated bearings. Check for heat radiated to your hand or check with a thermometer. Note that one of the most frequent conditions that cause bearings to overheat is excessive lubrication. This is a very

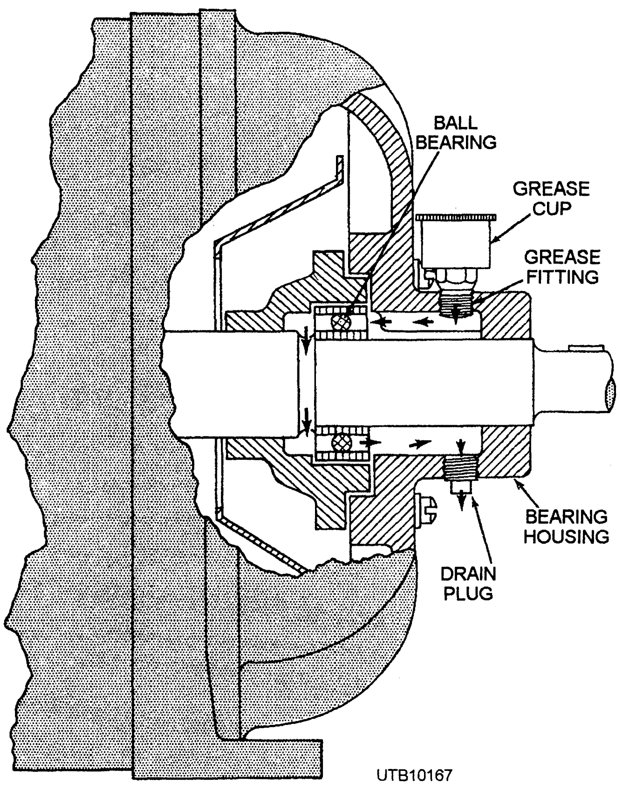

Figure 6-2.—Grease-lubricated ball bearings.

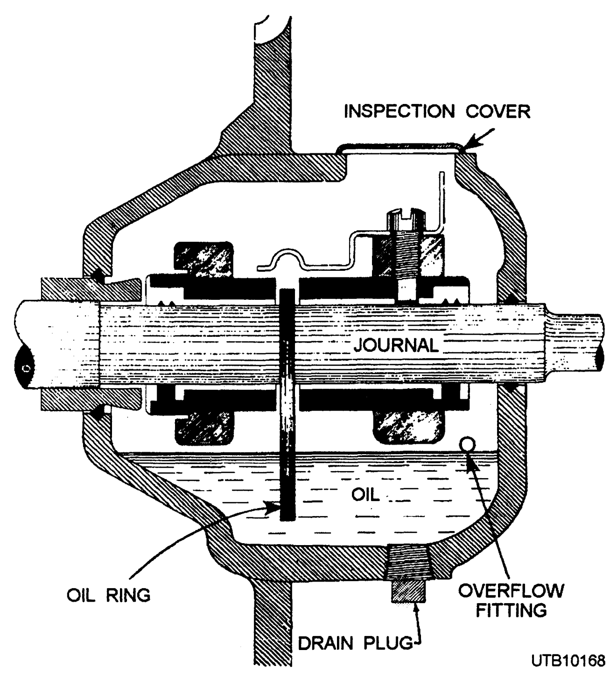

Figure 6-3.—Ring-oiled sleeve bearing.

common problem in the case of grease-lubricated bearings. Too much grease around the bearings insulates and seriously hinders the conduction of heat away from the bearing. The specific lubrication requirements and inspection procedures vary according to the type of bearings and the motor installation. You should always consult your local operator maintenance schedules and instructions for guidance. Other than the inspections cited, the operator should check for the leakage of lubricants from the bearings, especially lubricant oozing toward the windings or other electrical conductors.

At less frequent intervals, maintenance schedules require additional and more detailed inspections for proper lubrication. This requirement often includes dismantling parts of the bearing housing because bearing housings and pressure fittings must be cleaned periodically.

To lubricate grease-lubricated bearings properly, you must flush old grease from the bearing with solvent and add fresh grease. Sleeve bearings must be examined at various intervals and the oil reservoir flushed, cleaned, and refilled.

MAINTENANCE AND ALIGNMENT OF DRIVES.—The mechanism, or linkage, that transmits the motion and the power of the prime mover to the driven equipment is the drive. The drive must be maintained and operated properly, because its alignment and mechanical efficiency affects both the prime mover and the driven equipment. Two fairly common types of drives used with electric motors are the flexible coupling and the belt drive.

The coupling shown in figure 6-4 connects or couples the shaft of the prime mover to the shaft of the driven equipment. The coupling is designed to permit very slight misalignment between the two shafts. This flexibility permits the coupling to absorb some of the torque, or twisting force, resulting from the inertia of the driven equipment when the motor is started and brought up to speed. Caution must be taken, because any misalignment in excess of these small tolerances causes rapid wear of the coupling hubs and bushing pins, vibration of the shafts, and a reduction in the transmission of power from the prime mover. Vibration is transmitted through the shafts to moving or rotating parts of both the prime mover and the driven equipment. Vibration inevitably results in excessive wear of the various bearings that support the moving or rotating parts, which, in turn, results in more misalignment, vibrations, and wear. The point is that small vibrations, which at first may seem insignificant, can develop into major casualties and breakdowns.

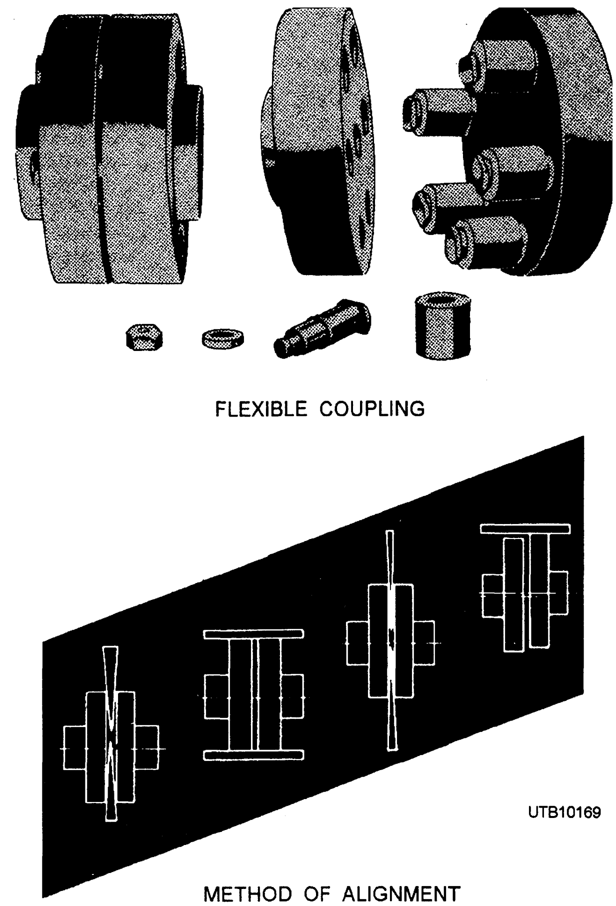

Figure 6-4.—Coupling.

While the motor is in operation, check the coupling for any unusual noise or vibration. At prescribed intervals, maintenance schedules require the operator to check the alignment of the coupling with a straightedge, a dial indicator, a thickness gauge, or a wedge, and realign the coupling as necessary. For detailed instructions for the proper realignment procedure, consult the manufacturer's instructions.

Various belt and pulley arrangements are also used as drives on electric motors. These belt drives are somewhat similar to the fan belt arrangements that drive the fan, the water pump, and the alternator on automobiles. The belt, made either of rubber or leather, rides on grooved pulleys or sheaves-one sheave connected to the shaft of the prime mover and the other sheave connected to the shaft of the driven equipment. In this way, the rotation of the electric motor is transmitted to the shaft of the driven equipment.

Belt drive maintenance requires proper belt tension. If the belt is too loose or slack, the power of the prime mover is not transmitted efficiently. Belt slippage also results in excessive rubbing and wear of the belt on the sheaves. Sheaves worn or out of alignment can also contribute to excessive belt wear. Additionally, belt slippage can be caused by an accumulation of oil or grease on the sheaves. If the belt is too tight, on the other hand, the stress is transmitted to the bearings in the sheaves and along the shafts. This condition causes excessive bearing wear and misalignment.

A properly adjusted belt has a very slight bow in the slack side when running. When idle, the belt has an "alive" springiness when thumped with the hand. Lack of this springiness indicates too little tension. A belt that is too tight feels dead when thumped with the hand.

While the motor is in operation, you should visually inspect the belt drive periodically for any indication of improper tension or slippage. Also, be careful to keep the belt and sheaves clean and free of grease or oil at all times. At prescribed intervals, inspect the belt for fraying, for cracks, or other unusual wear. You should also inspect and check the alignment of the sheaves. Excessive belt rubbing on the sheaves is an indication of belt slippage. Sheaves that are out of alignment are normally a result of excessive belt tension.

Occasionally, it may be necessary to replace a worn and frayed belt. If the drive has multiple belts, ALL the belts must be replaced with a set of matched belts. The belts in a matched set are machine-checked to ensure equal size and tension.

In addition to the maintenance and inspections outlined above, the operator must test and inspect other items related to the motor, such as control switchboards, pilot lamps, alarms, and circuit breakers. Electrical connections and conductors must also be periodically inspected for proper insulation and security.

SAFETY.—Because of the danger in working with electric motors, all safety precautions should be observed. In operating electric motors and in performing operator maintenance on electric motors, remember that you are working on a device which carries a force of energy that is not only useful but also deadly.

CLEANLINESS.—Cleanliness of electric motor operation and maintenance is largely a matter of prevention, rather than inspection and correction. As an operator, you must develop clean housekeeping and maintenance habits. Dirt, dust, and other foreign objects that accumulate on and inside an electric motor can reduce ventilation and foul moving parts. When dirt and grit accumulate on windings, the cooling or ventilation of these electrical conductors is seriously reduced. During the inspection routines, prevent lubricants and lubricant fittings from getting contaminated. Dirt in lube oil, in many cases, settles to the lowest point in the system before doing any extensive damage; however, dirt or grit that gets into lubricating grease can remain suspended indefinitely and result in abrasion of bearings and moving surfaces.

The maintenance schedule usually requires periodic inspection and cleaning of the rotor and the stator windings. Low-pressure compressed air can be used to blow out the dirt and dust; however, in the stator, this method can sometimes result in dirt being driven deeper into the windings. Instead, you should use vacuum suction. In fact, vacuum suction is always the preferred method for removing dust and dirt from stator windings or from any other motor component when compressed air could force dirt and abrasive particles deeper into the mechanism. Accumulations of grease and oil can be removed with the proper type of petroleum solvent. In any case, consult local maintenance schedules and instructions for the specific and precise cleaning method.

INTERNAL COMBUSTION ENGINES

An internal combustion engine is a machine that produces mechanical energy by burning fuel in a confined space (the engine cylinder). The term applies to both diesel and gasoline engines.

The Utilitiesman should have a basic knowledge of the principles of diesel and gasoline operation, since the Utilitiesman has to operate and hold first-echelon maintenance of the engine used to drive various types of pumps and compressors.

Operation and Maintenance of Diesel Engines

Diesel engines change heat energy into mechanical energy. Heat is developed when a mixture of compressed fuel and air burns inside a cylinder. A complete description of the internal combustion engine and its principles of operation is in chapter 12 of *Basic Machines,* NAVEDTRA 12199.

To keep diesel engines in peak operating condition, the operator must give careful attention to the following factors-prestart inspection, starting the diesel, securing the diesel, and operator maintenance.

Before a diesel can be started, the operator must perform a prestart inspection to ensure the engine is ready for operation. The specific inspection routine varies somewhat according to each engine. The basic procedure, however, requires the operator to inspect the engine for a sufficient supply of fuel oil, lube oil, and cooling water. The operator must also be alert for any leakage of these fluids. When replenishment of cooling water is necessary for the radiator, use clean or soft water to keep the engine water jackets and coolant circulating system free of sediment. If the engine is still hot from previous operation, do not add large amounts of cold water. Sudden cooling can crack cylinders or cylinder heads and may cause unequal contraction of the structural and working parts and lead to seizing of the pistons. When topping off batteries, use distilled water.

Accessories and drives should be inspected for loose connections and mountings. If the diesel starting system is battery equipped, check the batteries for cracks and leaks, and ensure the battery cables and vent caps are clean and secure.

As a safety precaution, inspect the fire extinguisher for ease of removal, full charge, security, and cleanliness of valves and nozzles before starting the engine.

Diesel engines rely on some external source of power for starting. The starting mechanism may be an electric motor, an auxiliary gasoline engine, compressed air, or even a hand-cranking mechanism. Whatever system is used, the starter forces the pistons to reciprocate and compresses air drawn into the cylinders. When sufficient compression has been developed with the aid of the starter, the temperature of the air in the cylinders will be high enough to ignite the injected diesel fuel. Thus internal combustion takes place and the engine begins to crank under its own power. Once the engine has been started, the actions the operator must take are as follows:

1. Throttle the engine to normal (fast idle) warm-up speed. The diesel should not be permitted to slow idle for any appreciable length of time because this causes the engine-driven blower to deliver an insufficient amount of air for complete combustion. This condition results in partially burned fuel oil, forming heavy carbon deposits that foul the valves, the piston rings, and the exhaust system.

2. Immediately check the lube oil pressure gauge. If the gauge does not indicate positive and sufficient lube oil pressure within 30 seconds, stop the engine immediately and report the difficulty to the proper authority.

3. Observe the temperature gauge during the warm-up period. The engine must not be placed under load until it reaches the proper warm-up temperature. Placing a cold engine under full load can result in serious damage to the engine because of poor lubrication at low temperature and uneven rates of expansion.

While the engine is in operation, other inspections and checks are required, such as checking of lube oil and fuel oil levels, filters and strainers, accessories and drives, and engine operating temperatures and pressures. Normally, the operator records the results of these inspections in an operating log.

When the diesel is secured, if the engine installation permits, let the engine low idle without load for a short time before stopping to allow for a gradual reduction of engine temperature. Once the diesel has been shut down, the standby lube oil pump should be kept in operation for a short time to allow the lube oil to further cool the engine. The cooling water should also be kept circulating for 15 to 30 minutes to bring the working parts to a low temperature without danger of distortion from one part cooling faster than another.

While the engine is cooling, the operator must check to determine the need for adjustment, for repair, and for replacement or renewal of parts. The required actions are as follows:

- Check the fuel, the oil, and the water as in the prestart inspection.
- Check the engine instruments or the gauges for proper readings.
- Check the accessories and the drives as in the prestart inspection.
- Inspect the air cleaners and the breather caps.
- Inspect the fuel filters.
- Inspect the engine controls and the linkage.
- Inspect the batteries as in the prestart inspection.
- Inspect all electrical wiring, insulation, and security of connections.

According to the prescribed maintenance schedules, the engine operator performs other inspections and maintenance duties. These maintenance routines occur at timed intervals prescribed by manufacturers. Examples of tasks that can be required by a maintenance schedule are as follows:

- Removing and cleaning the oil filterelements
- Inspecting the fuel lines, the fuel filters, and the fuel pump
- Cleaning the battery casings and the terminal posts; checking for proper electrolyte level and specific gravity
- Inspecting and lubricating the starting mechanism
- Inspecting, cleaning, and lubricating the generator; inspecting and testing the voltage and current regulator
- Inspecting the radiator; inspecting the water pump, the fan, and the drive belts
- Disassembling and cleaning the air filters and the breather caps
- Inspecting the crankcase, the valve covers, the timing gears, and the clutch housing
- Inspecting the cylinder heads and the gaskets

Operation and Maintenance of Gasoline Engines

Like the diesel engine, the gasoline engine changes heat energy into mechanical energy. The physical construction of the gasoline engine is very much the same as that of the diesel. Pistons, cylinders, valves, connecting rods, a crankshaft, and an engine block are in each. A cooling system carries heat away; a lubrication system reduces friction of moving parts; an air system supplies air for combustion in the cylinders; and a fuel system supplies fuel.

Most gasoline engines operate on the four-stroke cycle (fig. 6-5). The difference between gasoline and diesel engine operation is the method of introducing the fuel and the air into the cylinders and the means by which the compressed fuel and air are ignited in the cylinders.

In a diesel engine, the air is admitted to the cylinder on the intake stroke of the piston, as shown in view A, figure 6-5. The fuel oil is sprayed into the chamber AFTER the air has been compressed. In a gasoline engine, the fuel (gasoline) and air are mixed together BEFORE being admitted to the cylinder. The intake stroke of the piston sucks air through the air cleaner into the carburetor. In the carburetor, the clean air is mixed with gasoline (vaporized) from the fuel tank. The air and gas mixture continues on to the intake manifold that is connected to the cylinder head. An intake valve admits the air-gas mixture into the cylinder.

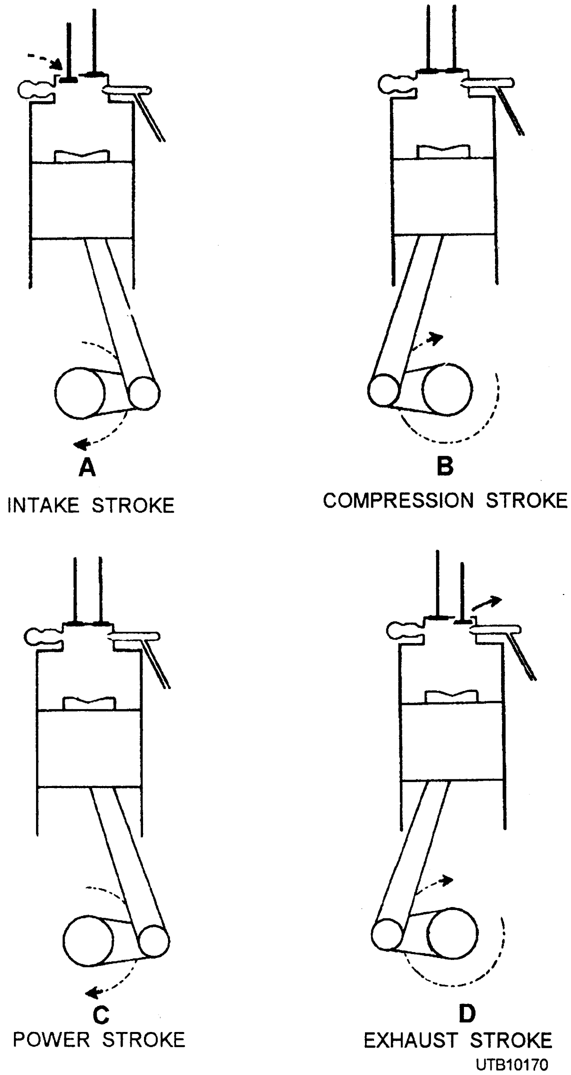

Figure 6-5.—Four-stroke cycle.

The diesel engine produces combustion by using the heat of compression, as shown in view B. In a gasoline engine, an electric SPARK is provided by the spark plug to ignite the air-gas mixture. Ignition occurs as the piston completes its compression stroke. The ignited gases expand and the piston is pushed down on the power stroke, as shown in view C. The exhaust stroke of the piston forces the burned gases out of the cylinder chamber, as shown in view D.

The operating procedures and operator maintenance routines for gasoline engines are essentially the same as those for diesel engines. Starting procedures for gasoline engines are also much the same as those for diesels; however. there is one important exception. Most gasoline engines are equipped with priming or choking devices to aid in starting a cold engine. Generally, these priming devices simply dump raw fuel into the cylinders; that is, the fuel is not thoroughly mixed with air or atomized before induction into the cylinders. This rich mixture of fuel aids in achieving initial combustion; however, not all of the fuel is burned. In other words, we have incomplete combustion. Prolonged or excessive choking during and after the start can lead to carbon deposits being built up in the engine. For this reason, the operator should always use care and restraint in choking or priming the engine. both during and after the start.

Securing procedures for gasoline engines are also basically the same as those for diesels. although some gasoline engine installations may not permit circulation of lube oil and coolant after the engine has been stopped.

As you might expect, operator maintenance routines for gasoline engines differ from those for diesels because of the slight differences in design and construction of gasoline engines. In other words, gasoline engine maintenance and inspection schedules must provide for the inspection, the adjustment, and the maintenance of such items as carburetors, chokes, ignition coils, wiring. distributors. and spark plugs.

SAFETY.—Anytime gasoline or diesel engines are secured for maintenance and inspection purposes, the operator should always guard against intentional or inadvertent starting of the engine by uninformed personnel. This rule applies to all types of prime movers, including electric motors. It also applies to maintenance and inspection operations being performed only on the driven equipment. Regardless of whether the work is being done on the prime mover itself or on the driven equipment alone. unintentional starting of the prime mover during the maintenance operation can result in serious damage to the machinery and serious injury to maintenance personnel. For this reason. YOU are responsible for using the equipment tag-out procedures contained in the current OPNAVINST 3120.32. In most situations, it may be a good idea to disable the starting mechanism completely, so even if personnel fail to see or read the tag, the prime mover cannot be started.

During the maintenance operation, the operator must keep a strict accounting of all tools and parts. Tools, nuts and bolts, or any other material left adrift can foul a moving part and completely disable the machinery during subsequent operation. There is another reason for keeping a strict accounting of parts whenever components are disassembled. Parts that work together wear together. The various parts of valve assemblies, bearing assemblies, and so forth, should be carefully marked and grouped during disassembly and replaced in the same position from which they were removed; otherwise, discrepancies in fitting and joining can result and reduce the mechanical efficiency of the moving parts. This can eventually lead to a breakdown.

WARNING

When an engine or a motor is inspected that is in operation, the operator should always be cautious while working near moving parts. Loose clothing, rags hanging from pockets, dangling key chains, and so forth, can easily become entangled with, or drawn into, moving parts, resulting in a serious accident.

CLEANLINESS.—Engine maintenance and inspection require cleanliness. Dirt allowed to accumulate on and around an engine can find its way inside that engine. It may be carried into the engine with air, fuel, lube oil, or water, or careless personnel may introduce it. Dirt can cause sludge and scale deposits that impair circulation of fuel, oil, and water, and erode moving parts. Large accumulations of dirt on external surfaces can insulate the surface and reduce cooling.

Normally, there are specific instructions available locally concerning cleanliness precautions while handling fuel and lube oil. You must know and observe these precautions. Some fundamental cleanliness precautions are as follows.

- Never use waste or linty rags around fuel or lube oil containers, fuel inspection equipment, or carburetors.
- Keep fuel and lube oil handling equipment, such as measures, funnels, and containers, clean and covered when not in use.
- Use clean, soft water in engine radiators and coolant systems to keep the engine water jackets free of sediment, and use distilled water in topping off batteries.

- Keep engine air intake filters clean to maintain sufficient induction of air.

Q1. An electric motor is what part of a pump?

Q2. Excessive rubbing or wear is a result of what condition caused by improper belt tension?

Q3. Before starting a diesel engine, you must complete what type of inspection?

Q4. Whatfeature is the difference between agasoline and a diesel engine?

PUMPS

LEARNING OBJECTIVE: *Identify specific types of pumps and the operation and maintenance procedures for each; identify methods used for installing piping, valves, and the maintenance of stuffing box, packing, and mechanical seals in pumps; and identify the methods used for the maintenance of internal pump components.*

A Utilitiesman is required to work with pumps of many shapes and size. Some of the primary uses of pumps are as follows:

- To supply feedwater to boilers
- To deliver fuel oil to oil-fired boilers
- To circulate coolants and lubricants in internal combustion engines
- To supply chemical feed in water purification systems,
- To lift water from cells and distribute it throughout a system
- To discharge sewage into setting tanks or mains.

The principles of pump operation, the principle of suction force, the types of valves used in pump operation, the different types of pumps, pump installation, and safety precautions that a Utilitiesman has to know to operate and maintain the various types of pumps used today are discussed in this section.

PUMP OPERATION

Pumps are used to move any substance that flows or can be made to flow. Most commonly, pumps are used to move water, oil, and other liquids; however, steam and other gases are also fluid and can be moved with pumps, as can molten metal, sludge, and mud.

A pump is a device that uses an external source of power to force fluid to move from one place to another. A pump develops no energy of its own; it merely transforms energy from the external source (steam turbine, electric motor) into mechanical kinetic energy, which is manifested by the motion of the fluid. This kinetic energy is then used to do work. For example. to raise liquid from one level to another, as when water is raised from a well. Other examples are to transport liquid through a pipe, as when oil is moved through an oil pipeline; to move liquid against some resistance, as when water is pumped to a boiler under pressure; or to force liquid through a hydraulic system, against resistance. Every pump has a POWER END, whether it is a steam turbine, a reciprocating steam engine, a steam jet. or some type of electric motor. Each pump also has a FLUID END, where the fluid enters (suction) and leaves (discharges) the pump.

The addition of energy to a liquid by a pump usually. results in an increase in pressure, which is generally referred to as HEAD. In pump operation, you should know that there are four types of head-net positive suction head, suction head, discharge head, and total discharge head. The definition of each of the types of head is as follows:

- The NET POSITIVE SUCTION HEAD (NPSH) is the suction pressure minus the vapor pressure expressed in feet of liquid at the pump suction. This type of head pressure is commonly referred to as NPSH.
- The SUCTION HEAD on a pump means the total pressure of the liquid entering the pump. In a de-aerating feed tank operating under saturated conditions. the suction head of the feed booster pump equals the NPSH plus the auxiliary exhaust pressure.
- The DISCHARGE HEAD means the pressureof liquid leaving the pump or the level of liquid with respect to the level of the pump on the discharge side.
- The TOTAL DISCHARGE HEAD is the net difference between the suction head and the discharge head.

NOTE: When positive, suction head is usually expressed in feet of water. When negative, it is expressed in inches of mercury.

When a pump operates below the level of a liquid, its suction end receives the liquid under a gravity flow. When the pump is located above the level of the liquid being pumped, the pump establishes a vacuum at the inlet to move the liquid into the pump. Atmospheric pressure, acting on the surface of the liquid, then provides the necessary pressure to move the liquid into the pump.

SUCTION FORCE

The principle of suction force, or suction lift, as applied to reciprocating pumps, is shown in figure 6-6. In diagram A, the piston cylinder is open at both the top and bottom, so the liquid level at A and B is the same. In diagram B, the cylinder is closed at the bottom. A piston has been inserted and partly withdrawn, thus creating a partial vacuum. When the foot valve (check valve) at the bottom of the cylinder opens (diagram C), as a result of the lower pressure in the cylinder, the liquid rises up into the cylinder, which causes the liquid level in the well to drop. Assuming the liquid is water and there is a perfect vacuum below the piston, atmospheric pressure pushes water up into the cylinder to a height of 34 feet, even though the piston may be raised higher than 34 feet.

You must understand that the preceding example is for the theoretical condition of a perfect vacuum. In practice, leakage between the piston and the cylinder, friction (fluid) in piping, and gases dissolved in the liquid limit the suction lift of a pump to a height of approximately 22 feet, as shown in diagram D of figure 6-6.

When a pump is pumping certain liquids, such as hot water, oil, or gasoline, some of the liquid vaporizes because of the vacuum on the suction side of the pump. The pump may become vapor bound and reduce the possible suction lift; this is called "cavitation."

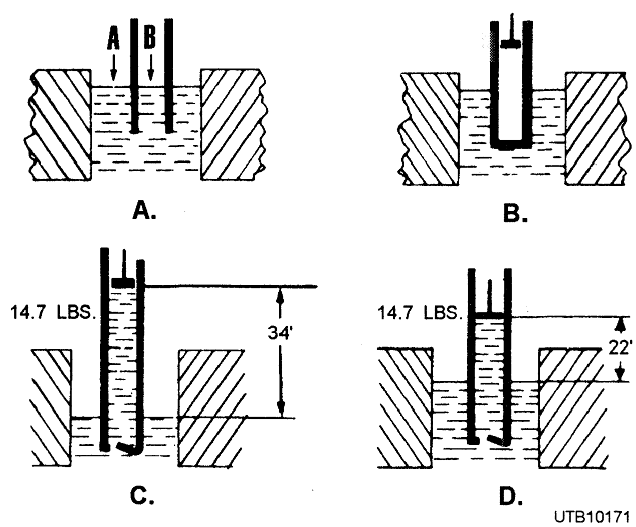

Figure 6-6.—Diagrams showing the principles of suction force.

The suction force principle applies to other types of pumps, as well as to the reciprocating type, though to a lesser degree and in a different manner. The centrifugal, the propeller, and the rotary pumps all use suction force to a certain extent. Here, a partial vacuum can be produced by the revolving mechanisms instead of by the reciprocating plunger. Also, centrifugal pumps are not self-priming because they do not pump air. Their casing must be flooded before they can function. In the eductor (jet pump), flow is maintained by the suction force created by a jet of water, compressed air, or steam passing through a nozzle at high velocity. These principles are explained later in this chapter.

VALVES USED WITH PUMPS

Every pump is equipped with devices for controlling the direction of flow, the volume of flow, and the operating pressure of the pump. A device that performs one or more of these control functions is called a VALVE.

A valve that permits liquid flow in only one direction is classified as a CHECK VALVE. In most cases, check valves open and close automatically; that is, they are kept closed or seated by spring tension or by the force of gravity until the liquid pressure above or below the valve overcomes the spring or gravity resistance and causes the valve to open. Check valves of this type are used with centrifugal pumps to control the suction and discharge of the liquid in the pump end at the proper time automatically. Figure 6-7 shows a vertical check valve. In this case, the valve is kept seated by its own weight or the force of gravity. If desired, it could also be kept closed by a spring.

Another type of valve in pump systems is the STOP VALVE. Stop valves are usually opened or

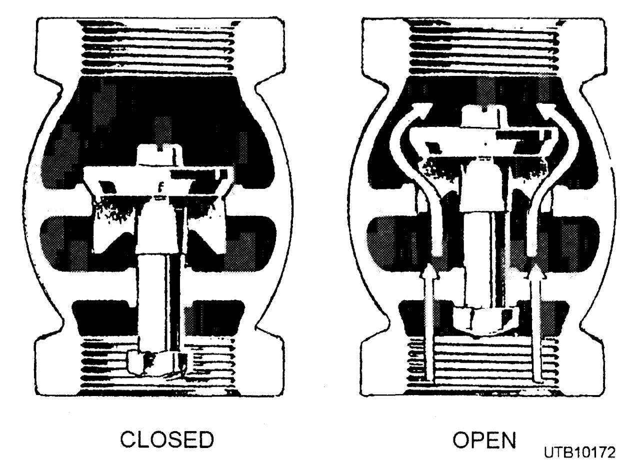

Figure 6-7.—Vertical check valve.

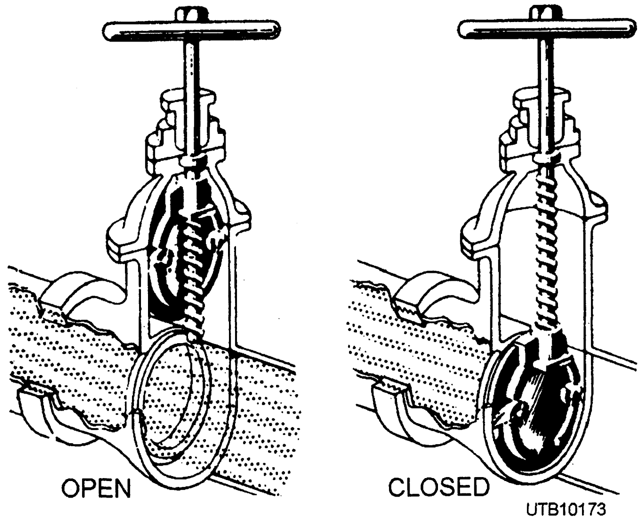

Figure 6-8.—Operation of a gate valve.

closed manually by means of a handwheel. They are used primarily to start or stop the flow of liquid through the pump during certain phases of operation. Thus stop valves are often placed on suction and discharge lines, so the pump is isolated or sealed off from the rest of the liquid system. Figure 6-8 shows the operation of a gate valve. A gate valve is a type of stop valve. A gate, or wedge, is raised or lowered by turning the handwheel. Some types of stop valves are used for throttling purposes; that is, to regulate the flow of liquid. However, gate valves are never recommended for throttling service because the flow of liquid past the partially opened gate can rapidly erode the gate face. Instead, the gate valve can be replaced with a tapered needle valve (another type of stop valve) which gradually opens or closes through the valve seat.

A third type of valve generally found on most types of pumps is the RELIEF VALVE. As you can see from figure 6-9, most relief valves are similar in their design to check valves. These valves are designed to open when the liquid pressure in the pump becomes dangerously high. In most cases, the outlet of the relief valve is connected to a recirculating line that passes the excess liquid back to the suction side of the pump. Almost all pressure relief valves are fitted with an adjusting nut or screw that permits the spring tension to be regulated. In this way, the pressure at which the valve is opened can be varied.

TYPES OF PUMPS

Pumps are classified according to the type of movement that causes their pumping action. The five broad categories of pumps are rotary, reciprocating, centrifugal, air lift, and jet pumps.

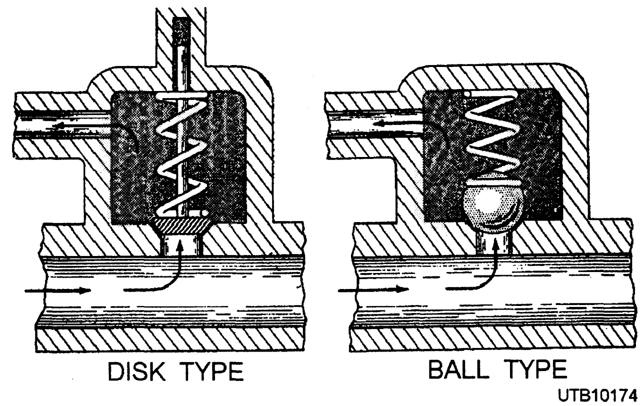

Figure 6-9.—Relief valve.

Rotary Pumps

All rotary pumps use the principle of entrapment and displacement of fluid by the rotating elements of various designs. These rotating parts, which may be gear teeth, screws, lobes, or vanes, trap the fluid at the suction inlet and remove it to the discharge outlet. Instead of "throwing" the water as in a centrifugal pump, a rotary pump traps it, pushes it around inside a closed casing, and discharges it in a continuous flow. Since rotary pumps move liquid by this method, they are often classified under the broad heading of positive displacement pumps.

Most rotary pumps have stuffing boxes provided at the rotor shafts to prevent excessive leakage at the shaft joint. In addition, various types of bearings can be fitted at the ends of the rotor shaft to minimize friction.

Generally, rotary pumps are self-priming; that is, the pump end need not be filled with liquid to initiate pumping action. Instead, the movement of the rotating elements creates a partial vacuum sufficient to lift or draw liquid into the pump and begin the pumping process. Note that self-priming and good suction lift are characteristics of the whole class of positive displacement pumps. Rotary pumps are less expensive and considerably simpler in construction. In the utilities field, rotary pumps are used for pumping fuel oil in boiler houses, for pumping chemical feed in water purification systems, for priming larger pumps, and for special applications, such as emergency pumps at fire-fighting stations.

TYPES OF ROTARY PUMPS.—The classification of a rotary pump is determined by the type of rotating element it has. However, no matter what form of rotating element is used, the basic principles of pump operation remain the same. In this section, two types of rotary pumps are discussed-the gear pump and the screw pump.

The GEAR PUMP is shown in figure 6-10. This type of pump uses two spur gears that rotate in opposite directions and mesh together at the center of the pump. One of the gears is coupled to the prime mover (usually an electric motor) and is called the driving gear. The other gear, which receives its motion by meshing with the driving gear, is called the driven gear. Note that liquid moves as the gear teeth rotate against the casing of the pump, thereby trapping the liquid and pushing it around to the discharge outlet. The meshing together of the two gears does not in itself move or pump liquid. The meshing of the gear teeth, in effect, forms a constant seal between the suction and discharge sides of the pump and thus prevents liquid from leaking back toward the suction inlet.

Very small clearances are permitted between the meshing gears and between the gear teeth and pump casing to avoid unnecessary friction and to allow the liquid being handled to act as a lubricant for the rotating parts. It is clear that when excessive clearances are allowed to develop between the gear teeth and casing or between the gears where they mesh that the efficiency of the pump is considerably reduced. For this reason, rotary pumps are rarely, if ever, used to handle corrosive or abrasive liquids.

Of the several types of SCREW PUMPS, the main difference is the number of intermeshing screws and the pitch of the screws. Figure 6-11 shows a positive displacement, double-screw, and low-pitch pump. Screw pumps are primarily used for pumping viscous fluids, such as JP-5 and diesel oil. Hydraulic systems use the screw-type pump as the pressure supply for the system. The pump may be either motor-driven or turbine-driven.

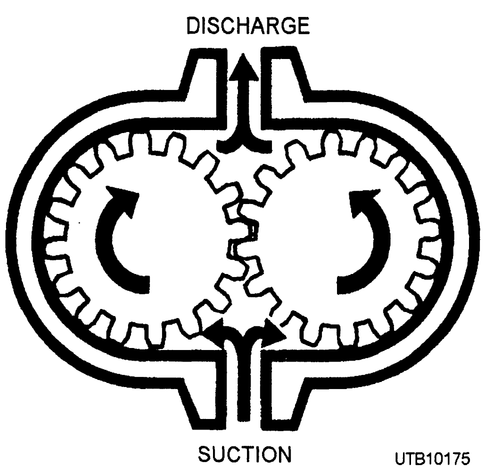

Figure 6-10.—Gear-type rotary pump.

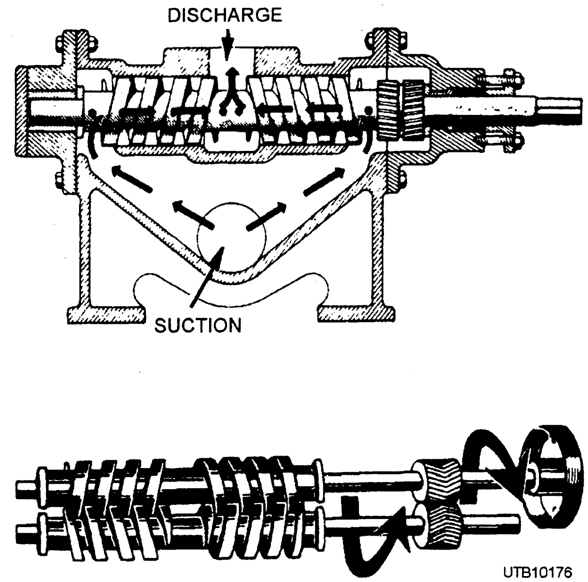

Figure 6-11.—Positive displacement, double-screw, low-pitch pump

In the screw pump, liquid is trapped and forced through the pump by the action of rotating screws. As the rotor turns, the liquid flows in between the threads at the outer end of each pair of screws. The threads carry the liquid along within the housing to the center of the pump where it is discharged.

OPERATION AND MAINTENANCE OF ROTARY PUMPS.—The rotary pump is susceptible to hydraulicking; therefore, the discharge stop valve must be in the OPEN position before the pump is started. In addition, it is a good operating practice to prime these pumps before operation when possible. This is particularly critical when the pump has been standing idle for a period of time. This is true in spite of the fact that rotary pumps are self-priming. Because the liquid handled in the pump lubricates the rotating elements of these pumps, filling the pump end with fluid before starting prevents unnecessary friction and wear of the rotating elements.

Rotary pump maintenance schedules stress that proper clearance be maintained between rotating parts. For this reason, there should be periodic checks for slippage. In addition, when the pump is dismantled, the actual clearances should be carefully measured and compared with the manufacturer's specifications.

Reciprocating Pumps

A reciprocating pump moves water or other liquid by means of a plunger or piston that reciprocates (travels back and forth) inside a cylinder. Reciprocating pumps are positive displacement pumps;

each stroke displaces a definite quantity of liquid, regardless of the resistance against which the pump is operating.

The standard way of designating the size of a reciprocating pump is by giving three dimensions, in the following order:

1. The diameter of the steam piston
2. The diameter of the pump plunger
3. The length of the stroke

For example, a 12- by 11- by 18-inch-reciprocating pump has a steam piston 12 inches in diameter, a pump plunger 11 inches in diameter, and a stroke of 18 inches. The designation enables you to tell immediately whether the pump is a high-pressure or low-pressure pump.

TYPES OF RECIPROCATING PUMPS.— Reciprocating pumps are usually classified as follows:

- Direct acting or indirect acting
- Simplex (single) or duplex (double)
- Single acting or double acting
- High pressure or low pressure
- Vertical or horizontal

The reciprocating pumps used by the Navy are usually one of the following types-direct-acting, simplex, double-acting, or vertical. The types most often used are direct acting pumps. The pump shown in figure 6-12 is direct acting because the pump rod is a DIRECT extension of the piston rod; and, therefore, the piston in the power end is DIRECTLY connected to the plunger in the liquid end. In an indirect-acting pump, there is some intermediate mechanism between the piston and pump plunger. The intermediate mechanism may be a lever or a cam. This arrangement can be used to change the relative length of strokes of piston and plunger or to vary the relative speed between piston and plunger. Or the pump may use a rotating crankshaft, such as a chemical proportioning pump in a distilling unit.

The diaphragm pump shown in figure 6-13 is a direct-acting reciprocating pump. It is commonly used by Utilitiesman to pump water from a ditch or sump.

Diaphragm pumps use a flexible diaphragm to move the liquid. The prime mover is usually a small gasoline or diesel engine with an eccentric connecting rod arrangement that converts rotary motion to reciprocating motion. On the suction stroke, the

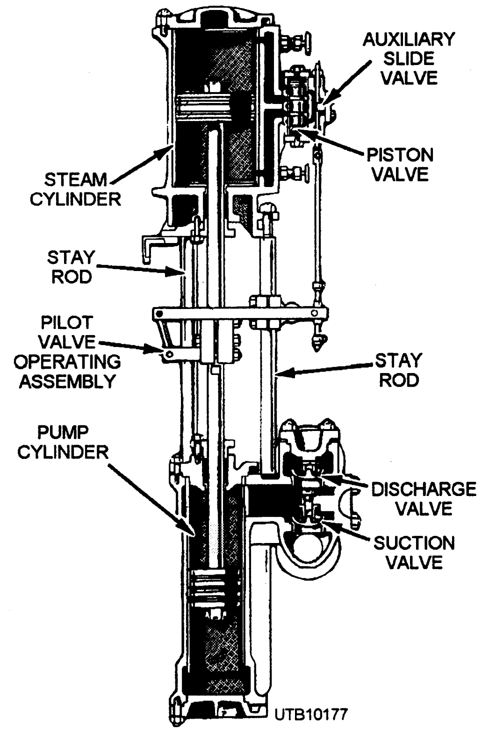

Figure 6-12.—Reciprocating pump.

diaphragm is drawn upward into a concave configuration. This movement of the diaphragm results in a partial vacuum that causes the suction ball valve to unseat (and at the same time keeps the discharge ball valve seated) and to admit the liquid to the pump cylinder. On the discharge stroke, the diaphragm is pushed downward, forcing the trapped liquid out through the discharge valve. Thus the liquid is made to move by the reciprocating motion of a flexible diaphragm.

Since the diaphragm forms an almost perfect seal in the pump cylinder between the liquid being pumped and the rest of the pump and driving mechanism, there is some danger of liquid abrasion or corrosion of moving parts behind the diaphragm. For this reason, diaphragm pumps are especially reliable for pumping mud, slime, silt, and other wastes or heavy liquids containing debris, such as sticks, stones, or rags. Liquid strainers are fitted at the suction inlet to prevent large objects from fouling the suction and discharge valves or from damaging the diaphragm.

You can use the diaphragm pump for dewatering trenches where sewer lines or waterlines are to be laid or for repairing breaks in waterlines or sewer lines.

Two of the most popular types of diaphragm pumps are the mud hog (closed discharge) and the water hog (open discharge). The MUD HOG is for

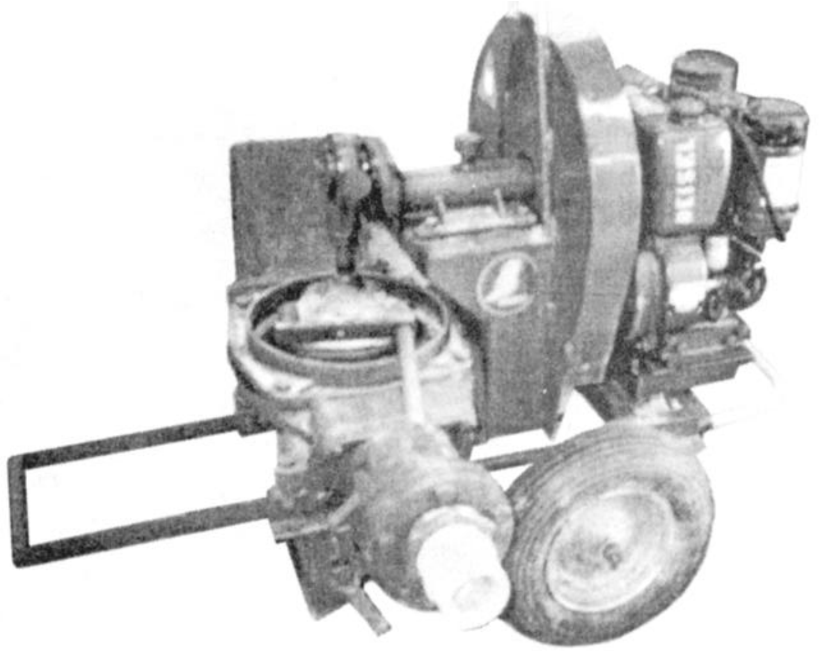

Figure 6-13.—Portable diaphragm pump.

pumping heavy and thick liquid long distances away from the pump. The pump is fitted with discharge hose connections, and the ball valves and chambers are designed to prevent fouling by sticks, stones, rags, and so on. The WATER HOG is used for pumping thinner and less viscous liquids; however, it can handle liquids containing sand, gravel, and mud. The discharge outlet from the water hog is open to permit free flow and increased discharge capacity. Thus the liquid is discharged directly at the pump. However, a discharge hose can be fitted to the pump if desired; but, the efficiency is reduced. Both the mud hog and water hog can be of either the simplex or duplex type.

Because of the nature of the liquids handled by diaphragm pumps, operator inspection during pump operation becomes particularly important. Make frequent inspections of the suction inlet strainer to prevent accumulation of debris that can reduce suction efficiency. Most diaphragm pump installations also permit easy access to the suction and discharge ball valves. The valve mechanisms can be inspected frequently to detect scoring, fouling, and improper valve seating. Because the diaphragm and ball-check valves are subjected to the corrosive action of such material as sand and gravel they require frequent attention. Therefore, operator maintenance schedules stress a continuing program of inspection and cleaning of these parts. In most cases, it is not practical to repair damaged or worn diaphragms and valves. They should be replaced with new ones; therefore, keep an adequate supply of these parts readily available.

The reciprocating pump shown in figure 6-12 is called a single or simplex pump because it has only one liquid cylinder. Simplex pumps are either direct acting or indirect acting. A double or duplex pump is an assembly of two single pumps placed side by side on the same foundation; the two steam cylinders are cast in a single block, and the two liquid cylinders are cast in another block. In a single-acting pump, the liquid is drawn into the liquid cylinder on the first or SUCTION STROKE and is forced out of the cylinder on the return or DISCHARGE STROKE. In a double-acting pump, each stroke serves both to draw in the liquid and to discharge the liquid. As one end of the cylinder is filled, the other end is emptied; on the return stroke, the end that was just emptied is filled and the end that was just filled is emptied. The pump shown in figure 6-12 is double acting, as are most of the reciprocating pumps used in the Navy. (NOTE: Only one of two sets of valves is shown in figure 6-12.)

The pump shown in figure 6-12 is designed to operate with a discharge pressure higher than the pressure of the steam operating the piston in the steam cylinder; in other words, it is a high-pressure pump. In a high-pressure pump, the steam piston is larger in diameter than the plunger in the liquid cylinder. Since the area of the steam piston is greater than the area of the plunger in the liquid cylinder, the total force exerted by the steam against the steam piston is concentrated on a smaller working area of the plunger in the liquid cylinder. Because of this factor, the pressure per square inch is greater in the liquid cylinder than in the steam cylinder. A high-pressure pump discharges a comparatively small volume of liquid against high pressure. A low-pressure pump, on the other hand, has a comparatively low discharge pressure but a larger volume of discharge. In a low-pressure pump, the steam piston is smaller than the plunger in the liquid cylinder.

Finally, the pump shown in figure 6-12 is classified as vertical because the steam piston and the pump plunger move up and down. Most reciprocating pumps in naval use are vertical; however, you may occasionally encounter a horizontal pump where the piston moves back and forth instead of up and down.

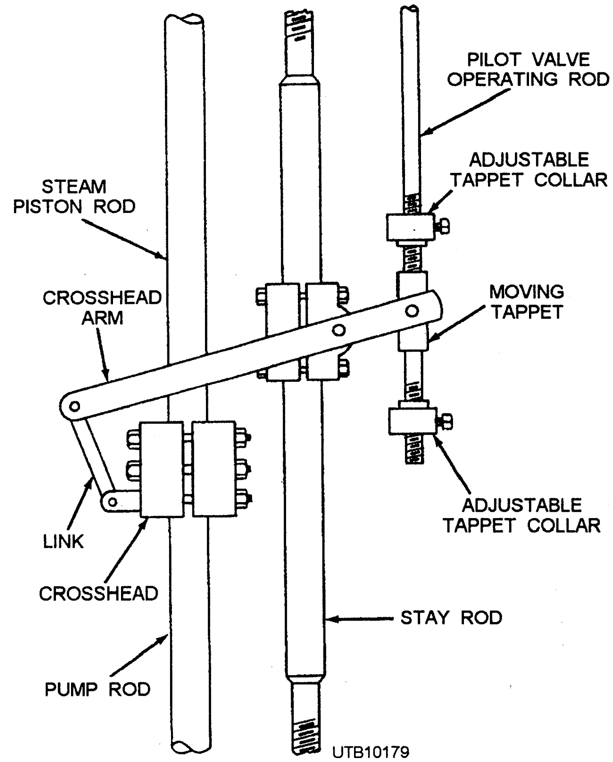

Figure 6-14.—Valve operating assembly for reciprocating pump.

OPERATION AND MAINTENANCE OF RECIPROCATING PUMPS.—The power end of a reciprocating pump consists of a bored cylinder in which the steam piston reciprocates. The steam cylinder is fitted with heads at each end; one head has an opening to accommodate the piston rod. Steam inlet and exhaust ports connect each end of the steam cylinder with the steam chest. Drain valves are installed in the steam cylinder, so water, resulting from condensation, can be drained off.

The admission and release of steam to and from each end of the steam cylinder are automatically timed by a valve operating assembly (fig. 6-14) that connects the pilot valve operating rod and the pump rod. As the crosshead arm (sometimes called the rocker arm) is moved up and down by the movement of the pump rod, the moving tappet slides up and down on the pilot valve rod. The tappet collars are adjusted, so the pump makes the full-designed stroke.

The piston-type valve gear, commonly used for automatic timing, consists of a piston-type slide valve and a pilot slide valve. The position of the pilot slide valve is controlled by the position of the main piston in the steam cylinder. At the completion of the downstroke of the pump, the crosshead arm moves the moving tappet against the upper adjustable tappet collar to actuate the pilot slide valve that admits steam to reposition the floating piston. The movement of the floating piston opens ports to admit steam to the underside of the piston in the steam cylinder and to exhaust the steam above the piston, thus causing the piston to move upward. Once the pump has completed the upstroke, the cycle repeats itself in reverse.

Reciprocating pumps are easy to operate and usually are very reliable units; however, they require routine maintenan ce and occasional repair work. Consult the manufacturer's technical manual for details on the repair of a specific unit. Before repairing or examining a pump, assemble the pertinent blueprints, drawings, and available data. These drawings and data furnish the required clearances, tools to be used, measurements, information on materials to be used, and other important data. In addition, you should have the complete history of the pump being repaired so you know what has been done, when repairs were last made, and what kind of trouble has been encountered before with this pump.

Remember that the steam end of a reciprocating pump should NOT be dismantled until a thorough check reveals that the water end is satisfactory. Most reciprocating pump troubles result from fouled water cylinders, from worn valves, or from faulty conditions in the pipe connections external to the pump.

Centrifugal Pumps

When a body, or a liquid, is made to revolve or whirl around a point, a force is created that impels the body or fluid to move outward from the center of rotation. This phenomenon is called CENTRIFUGAL FORCE. It is from this force that the centrifugal pump got its name.

The basic centrifugal pump has only one moving part-a wheel or impeller that is connected to the drive shaft of a prime mover and rotates within the pump casing. The design, or form, of the impeller varies somewhat. However, whatever its form, the impeller is designed to impart a whirling or revolving motion to the liquid in the pump. When the impeller rotates at relatively high speeds, sufficient centrifugal force is developed to throw the liquid outward and away from the center of rotation. Thus the liquid is sucked in at the center or eye of the impeller (center of rotation) and discharged at the outer rim of the impeller. Note that by the time the liquid leaves the impeller, it has acquired considerable velocity. In this connection, a fundamental law of liquid physics states, in part, that as the velocity of a fluid increases, the pressure or pressure head of that fluid decreases. Therefore, the liquid discharge from the impeller has a high velocity but low pressure. Before the liquid can be discharged from the pump, an INCREASE in pressure is necessary. In other words, the primary concern in practically all pumping systems is to maintain the discharge pressure so liquid can be distributed effectively throughout the system. In centrifugal pumps, a device is required to decrease the velocity of the impeller discharge and thereby increase the liquid pressure at the discharge outlet.

One method of increasing the discharge pressure of centrifugal pumps is by providing additional impellers. Pumps with only one impeller are SINGLE STAGE. Pumps with two or more impellers are MULTISTAGE. In multistage pumps, two or more impellers are placed on a common shaft (within the same pump housing) with the discharge of the first impeller being led into the suction of the next impeller, and so on. As the liquid passes from one stage to the next, additional pressure is imparted to it. In this fashion, the final discharge pressure of the pump can be increased considerably.

TYPES OF CENTRIFUGAL PUMPS.— Centrifugal pumps are also HORIZONTAL or VERTICAL, depending upon the position of the pump shaft. Generally, large, multistage, high-capacity pumps are horizontal. Most other pumps are vertical. The impellers used on centrifugal pumps may be SINGLE SUCTION or DOUBLE SUCTION. The single-suction impeller allows liquid to enter the eye from one direction only; the double-suction type allows liquid to enter the eye from two directions.

Impellers are CLOSED or OPEN. Closed impellers have sidewalls extending from the eye to the outer edge of the vane tips; open impellers do not have these sidewalls. Most centrifugal pumps in the Navy have closed impellers.

In the VOLUTE type of centrifugal pump shown in figure 6-15, the impeller discharges into a volute or gradually widening channel in the pump casing. As the liquid passes into the expanding neck of the volute, its velocity is considerably diminished; and, with this decrease in velocity, the pressure increases.

Another variation is the DIFFUSER or VOLUTE TURBINE type of centrifugal pump shown in figure 6-16. In this pump, the impeller discharges into

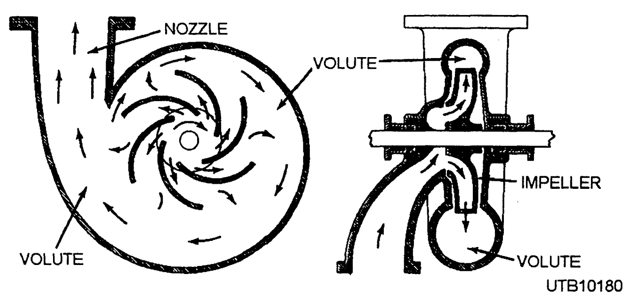

Figure 6-15.—Volute pump.

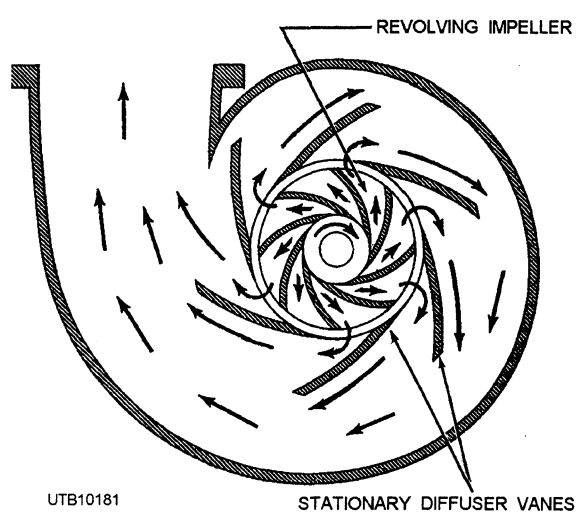

Figure 6-16.—Diffuser-type centrifugal pump.

stationary diffuser vanes surrounding the impeller. The diffuser vanes force a rather radical change in the direction of the impeller discharge, and this, in turn, slows down the discharge. In addition, the diffuser vanes form volutes of their own that further diminish the velocity of the discharge. Finally, the discharge from the diffuser vanes flows along the pump casing which, like the simple volute-type pump, is also in the form of a volute. Thus the diffuser-type pump provides for a nearly complete decrease in velocity and consequently an increase in discharge pressure.

The types of centrifugal pumps used for pumping sewage do not use diffuser vanes. The reason for this is that the rapid change in the direction of the impeller discharge can cause suspended matter in the liquid to come out of suspension and form deposits that corrode and foul moving parts.

Other types of centrifugal pumps, known as turbine well pumps, are used to pump wells. To produce sufficient discharge pressure, you must equip these pumps with a multistage impeller arrangement that is contained in volutes, referred to as bowls. To ensure satisfactory suction, set the impellers and bowls below the lowest drawdown or pumping level that the water in the well is expected to reach.

USE OF CENTRIFUGAL PUMPS.—The applications of centrifugal pumps are numerous; however, these pumps are most often used in buildings for the following purposes:

- To pump the general water supply. This includes both the overhead and pneumatic tank systems. In general water supply systems where the pump takes off directly from the city pressure main or where no suction lift is required, a centrifugal pump can be used. When a centrifugal pump is being used with a suction lift of no more than 15 feet is required, a pump with an automatic primer or a suction line equipped with a foot valve may be used.

- To provide booster service. In booster service, centrifugal pumps with in-take pressures from the city main operate only to boost this pressure. They may run continuously or automatically. When the automatic type is not operating, the water flows by city pressure through the impellers.

- To pump the domestic water supply. In domestic water supply systems, the centrifugal pump is used in shallow wells (suction lift not over 22 feet), in deep wells (for greater depths than 22 feet), and in a complete pneumatic system with electric motors or gasoline engines.

- To support the fire protection systems. Fire pumps usually are the centrifugal type, either single or multistage. Electricity, steam, or gasoline may drive them. Whatever the power supply, it must be permanent and, if steam, must have a constant minimum pressure of 50 pounds of steam. The pumps should agree with the specifications of the NFPA. Booster fire pumps have a low head to boost the pressure of the already available city supply

- To provide a hot-water circulating service. Hot-water circulating pumps are centrifugal. They move water in a closed system and thus usually require only a low head, though the static pressure in the systems may be high. The pumps should be selected with attenti on to strength of casing, efficient stuffing box, freedom from air and vapor binding, and flexible mounting.

- To provide sump drainage. Sump pumps are not classified as sewage pumps; however, they can be used as such. They may be vertical or horizontal centrifugal. The vertical type sump pump usually has the impeller submerged and the motor mounted above the pit. Units are equipped with an automatic switch operated by the float and are available in single or duplextype (fig. 6-17).

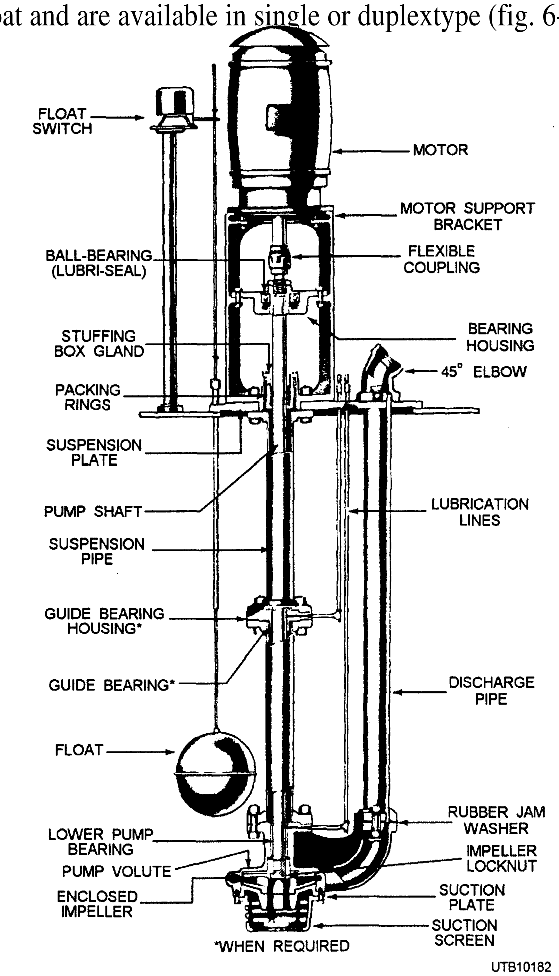

Figure 6-17.—Vertical submerged-type of centrifugal pump for sewage.

- To pump sewage. Sewage ejector pumps (fig. 6-18) for dry-pit installations have a connection on the suction end of the pump that is piped to a separate wet pit.

The dry-basin type of sewage ejector pump equipment includes the following:

- The pump with suction and discharge piping up to the floor plate
- An electric motor, a steel ejector basin with separate sewage and pump compartments
- A high-water alarm
- An automatic alternator
- Float switches
- A floor-mounted control panel
- Motor switches
- Automatic starters
- An iron access ladder
- Complete basin covers welded or riveted to the basin

The wet-basin (duplex wet-basin nonclog sewage ejector) type of sewage ejector pump equipment includes the following:

- The pump and fittings
- Electric motors
- Float switches

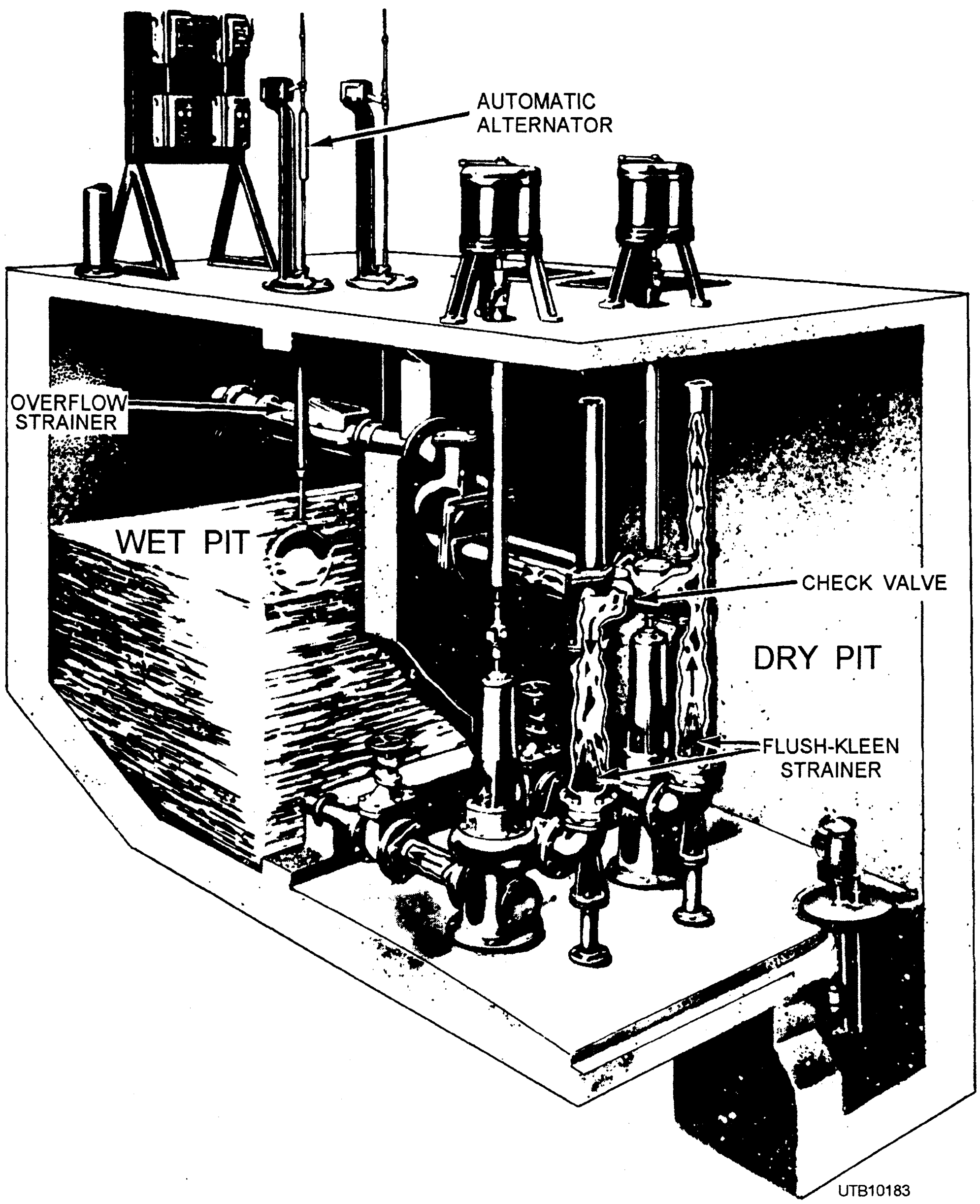

Figure 6-18.—Sewage ejector centrifugal pumps.

- An automatic alternator
- High-water alarm
- Motor switches
- Automatic starters

The centrifugal type of sewage pump has nonclogging impellers. It can be installed in either a horizontal configuration or in a vertical configuration with a suction lift. The centrifugal pump can be placed in either a wet or dry pit and is equipped with a float or diaphragm for automatic operation.

ADVANTAGES AND DISADVANTAGES OF CENTRIFUGAL PUMPS.—The advantages of centrifugal pumps include simplicity, compactness, weight saving, and adaptability to high-speed prime movers. One disadvantage of centrifugal pumps is their relatively poor suction power. When the pump end is dry, the rotation of the impeller, even at high speeds, is simply not sufficient to lift liquid into the pump; therefore, the pump must be primed before pumping can begin. For this reason, the suction lines and inlets of most centrifugal pumps are placed below the source level of the liquid pumped. The pump can then be primed by merely opening the suction stop valve and allowing the force of gravity to fill the pump with liquid. The static pressure of the liquid above the pump also adds to the suction pressure developed by the pump while it is in operation. Another disadvantage of centrifugal pumps is that they develop CAVITATION. Cavitation occurs when the velocity of a liquid increases to the point where the consequent pressure drop reaches the pressure of vaporization of the liquid. When this happens, vapor pockets, or bubbles, form in the liquid and then later collapse when subjected to higher pressure at some other point in the flow. The collapse of the vapor bubbles can take place with considerable force. This effect, coupled with the rather corrosive action of the vapor bubbles moving at high speed, can severely pit and corrode impeller surfaces and sometimes even the pump casing. In extreme instances, cavitation has caused structural failure of the impeller blades. Whenever cavitation occurs, it is frequently signaled by a clearly audible noise and vibration (caused by the violent collapse of vapor bubbles in the pump).

Several conditions can cause cavitation, not the least of which is improper design of the pump or pumping system. For example, if the suction pressure is abnormally low (caused perhaps by high suction lift or friction losses in the suction piping), the subsequent pressure drop across the impellers may be sufficient to reach the pressure of vaporization. A remedy might be to alter the pump design by installing larger piping to reduce friction loss or by installing a foot valve to reduce suction lift.

Cavitation can also be caused by improper operation of the pump. For instance, cavitation can occur when sudden and large demands for liquid are made upon the pump. As the liquid discharged from the pump is rapidly distributed and used downstream, a suction effect is created on the discharge side of the pump. Think of it as a pulling action on the discharge side that serves to increase the velocity of the liquid flowing through the pump. Thus, as the pressure head on the discharge decreases, the velocity of the liquid flowing across the impellers increases to the point where cavitation takes place. Perhaps the easiest way to avoid this condition is to regulate the liquid demand. If this is not possible, then increase the suction pressure by some means to maintain pressure in the pump under these conditions.

OPERATION AND MAINTENANCE OF CENTRIFUGAL PUMPS.—The operating procedures and maintenance schedules for centrifugal pumps are generally similar to those of the other pumps we have discussed previously. Centrifugal pumps are also fitted with stuffing boxes and various types of bearings that, of course, require periodic maintenance and inspection. Always refer to the manufacturer's instructions and locally prepared maintenance schedules for operating and maintenance procedures.

One operating practice is common to nearly all types of centrifugal pumps. Unlike positive displacement pumps, the discharge stop valve on centrifugal pumps must. be CLOSED before starting the pump. This action allows the pump to work against the sealed discharge and builds up an effective pressure head before attempting to move and distribute the liquid downstream. After the pump is up to speed and the discharge valve is opened, the pump continues to maintain that pressure head unless the operating conditions are altered. Note that there is no danger of hydraulicking while the pump is run with the discharge closed. If the centrifugal pump were to continue operation with the discharge sealed, it would simply build up toward its maximum discharge pressure. It would then begin to churn the liquid; that is, the discharge pressure would overcome the suction pressure and the liquid would continually slip back to the suction side of the pump. Nothing more would happen, except the pump would build up heat, since the liquid would not be able to carry away the heat generated by the moving parts.

There are several exceptions to the rule outlined above. For instance, when there are other pumps operating in parallel with the centrifugal pump discharging into a common system, these pumps provide the centrifugal pump with an effective pressure head to start against. Another exception is the turbine well pump. This pump always has a pressure head to start against, provided by the weight or static pressure of the water above the impellers. Therefore, a turbine well pump can usually be started with the discharge valve in the OPEN position. In the paragraphs below a few important aspects of pump operation and maintenance are discussed in detail.

One aspect of pump operation and maintenance is PACKING. Although this topic is included here under the general heading of centrifugal pumps, packing is used on many other types of pumps as well. Figure 6-19 shows packing installation procedures for centrifugal pumps. Packing is a general term that refers to many different types of materials used to seal moving machinery joints (sliding pistons and piston rods, rotating shafts and valve stems, etc.) against leakage of steam or liquids. As such, packing can be thought of as a close fitting bearing that must not onlv

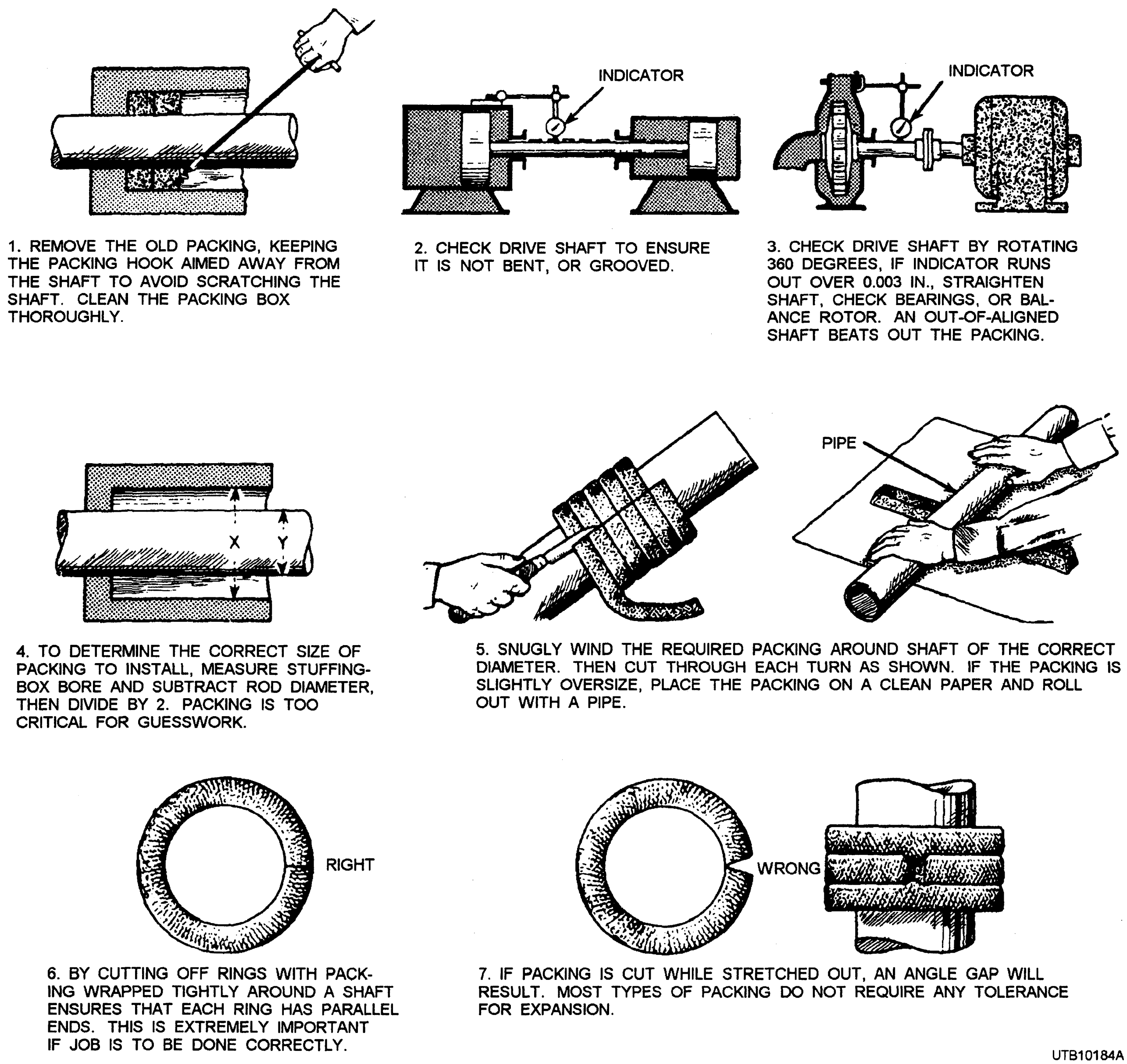

Figure 6-19.—Packing installation procedures.

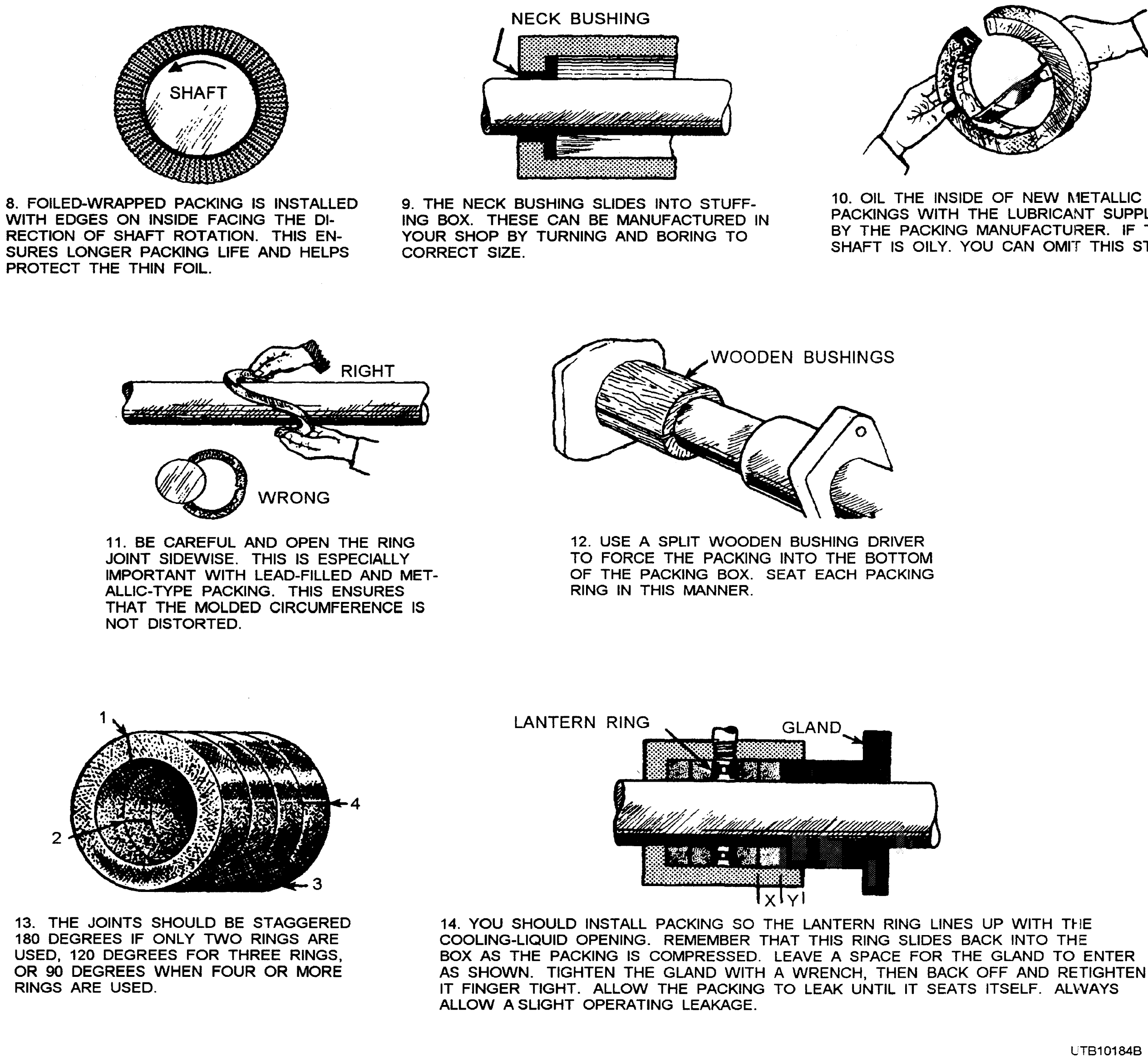

Figure 6-19.—Packing installation procedures-Continued.

prevent leakage but must also do this without causing excessive friction and undue wear of the moving part. Although most packing has definite lubricating qualities of its own, lubrication is enhanced by permitting small amounts of liquid or steam to leak past or through the packing. If the pump is used for corrosive or abrasive fluids, then some other form of lubricant, such as grease or oil, must be fed to the packing through external means.

Packing usually takes the form of coils, rings, or spirals. The packing is inserted into a stuffing box fitted around the sliding or rotating joint. The compression of the packing around the joint is controlled by hand-adjusted gland nuts.

The selection of the proper type of packing for a pump is important. There is no general-purpose or all-purpose packing. The specific type of packing that must be used depends on several factors, such as whether the packing seals a rotating or sliding joint and the type of liquid handled by the pump. In any event, you do not have to select the packing. Locally prepared guides and manufacturer's instructions specify what type of packing material to use. Upon receipt of the packing, note its condition and the use date stamped on the package to help you determine the shelf life of the packing. If a package has become unsealed, reseal it. Better yet, ensure the packing is used before its expiration date.

Packing requires frequent inspection and adjustment, particularly while the pump is in operation. The gland nuts must be adjusted with care, so ail the packing is compressed evenly and equally around the joint. If not, excessive and uneven wear of the packing can result, and the rotating or sliding shaft could become scored or grooved.

When a pump is first started, lubrication of the packing may be relatively poor. Because of initial friction, the packing may heat up and expand, thereby compressing itself around the joint and further reducing lubrication or leakage. Merely loosening or backing off the gland nuts is not always the best solution, because the liquid pressure in the pump can force the complete set of packing to move outward in the stuffing box. In this instance, the pump has to be shut down and the stuffing box allowed to cool. Several restarts may be necessary before the stuffing box runs cool.

Additional packing procedures are too extensive to be covered here. The primary purpose of this discussion of packing is to alert you to the importance of this pump component. It has been said that the proper inspection, adjustment, and upkeep of the packing are the most abused aspects of pump operation and maintenance.

Another important aspect of pump operation and maintenance is the understanding of mechanical seals. Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on centrifugal pumps. Pumps fitted with mechanical seals eliminate excessive stuffing box leakage that results in pump and motor bearing failures and motor winding failures. Mechanical seals are ideal for pumps operating in closed systems, such as air-conditioning and chilled water systems.

Type 1 mechanical seal is shown in figure 6-20. Spring pressure keeps the rotating seal face snug against the stationary seal face. The rotating seal and all of the assembly below it are affixed to the pump shaft. The stationary seal face is held stationary by the seal gland and packing ring. A static seal is formed between the two seal faces and the sleeve. System pressure within the pump assists the spring in keeping the rotating seal face tight against the stationary seal face. The type of material used for the seal faces

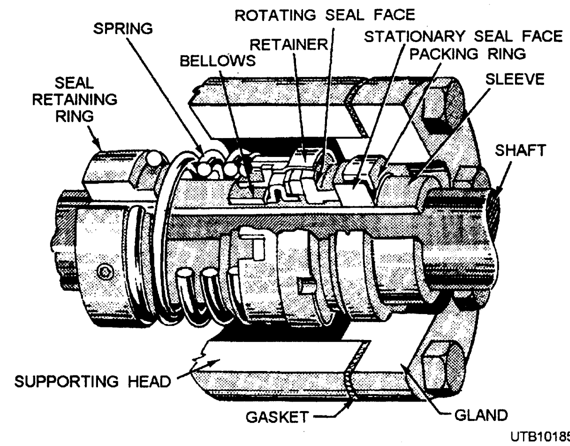

Figure 6-20.—Type 1 mechanical seal.

depends upon the service of the pump. Most water service pumps use a carbon material for the seal faces. When the seals wear out, they are replaced. New seals should not be touched on the sealing face because body acid and grease cause the seal face to pit prematurely and deteriorate.

Mechanical seals should be replaced whenever the seal is removed for any reason or whenever the leakage rate exceeds 5 drops per minute.

Mechanical seals are positioned on the shaft by means of stub or step sleeves. Mechanical seals should not be positioned by the use of setscrews. Shaft sleeves are chamfered on outboard ends to provide ease of mechanical seal mounting. Mechanical seals ensure that positive liquid pressure is always supplied to the seal faces and that the liquid circulates well at the seal faces to minimize the deposit of foreign matter on the seal parts.

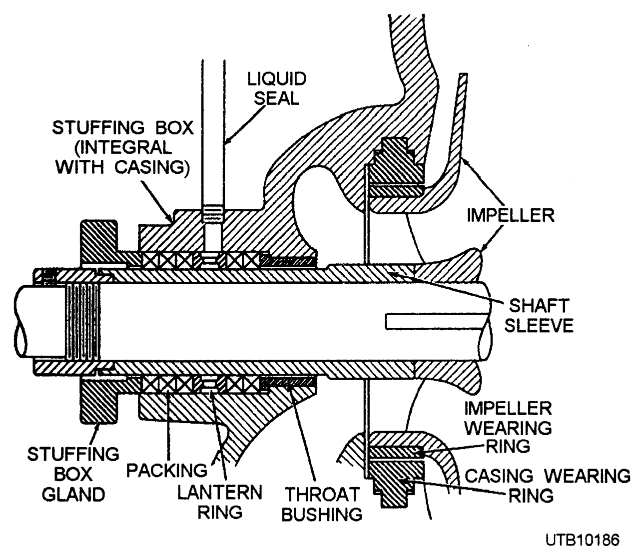

Figure 6-21.—Stuffing box on centrifugal pump.

When a stuffing box is fitted with a lantern ring, be sure to replace the packing beyond the lantern ring at the bottom of the stuffing box, and be sure that the sealing water connection to the lantern ring is not blanked off by the packing (fig. 6-21). Sleeves fitted at the packing on the pump shafts must always be tight. These sleeves are usually made secure by shrinking or keying them to the shaft. Be careful to ensure the water does not leak between the shaft and the shaft sleeves.

In some pumps, the shaft sleeve is pressed onto the shaft tightly by means of a hydraulic press, and the old sleeve must be machined off in a lathe before a new one can be installed. On other centrifugal pumps, the shaft sleeve is a snug slip-on fit, butted up against a shoulder on the shaft and held securely in place with a nut. On some small pumps, new sleeves can be installed by removing the water end casing, impeller, and old shaft sleeves. New sleeves are carried as repair parts, or they can be made in the machine shop. On large pumps, the sleeves are usually pressed on; these pumps must be disassembled and taken to the machine shop, a repair ship, or a Navy yard to have the old sleeve machined off and a new one pressed on.

Some sleeves are packed to prevent water leakage between the shaft and the sleeve, while some have O rings between the shaft and the abutting shoulder. For detailed information, consult the appropriate manufacturer's technical manual or applicable blueprints.

Shaft alignment must be checked frequently. When the shafts are out of line, the unit must be realigned to prevent shaft breakage and damage to the bearings, the pump casing wearing rings, and the throat bushings. Shaft alignment should be checked with all piping in place.

A FLEXIBLE COUPLING may connect the driving unit to the pump. You should remember that flexible couplings (fig. 6-22) are intended to take care of only slight misalignment. Misalignment should never exceed the amount specified by the pump manufacturer. When there is excessive misalignment, the coupling parts are punished severely, and pins, bushings, and bearings have to be frequently replaced.

The driving unit may be connected, or coupled, to the pump by a FLANGE COUPLING. Frequent realignment of the shaft may be necessary. Each pump shaft must be kept in proper alignment with the shaft of the driving unit. Abnormal temperatures, abnormal noises, and worn bearings or bushings indicate misalignments.

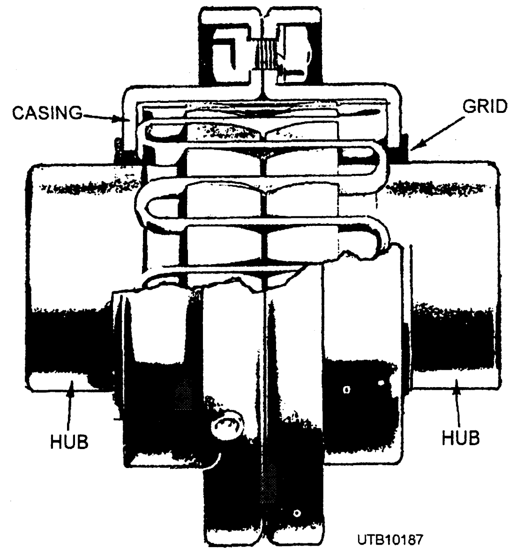

Figure 6-22.—Grid-type flexible coupling.

Wedges, or shims, are placed under the bases of both the driven and driving units to facilitate alignment when the machinery is installed. Jacking screws can also be used to level the units. When the pump or driving unit, or both, need to be shifted sideways to align the couplings, side brackets are welded in convenient spots on the foundations, and large setscrews are used to shift the units sideways or endwise. When the wedges or other packing have been adjusted so the outside diameters and faces of the coupling flanges run true as they are manually revolved, the chocks should be fastened, the units should be securely bolted to the foundation, and the coupling flanges should be bolted together.

These ALIGNMENTS MUST BE CHECKED from time to time and misalignments promptly corrected. There are three devices in use for checking the alignments-a 6-inch scale, a thickness gauge, and a dial indicator.

Shaft alignment should be checked whenever the pump is opened up and whenever a noticeable vibration is observed. When shafts are found out of line or inclined at an angle to each other, the unit should be aligned to avoid shaft breakages and renewal of bearings, pump casing wearing rings, and throat bushings. The appropriate technical manual should be consulted when you are aligning the pump.

In a centrifugal pump installation fitted with an internal water-lubricated bearing inside the pump casing (such as condensate pumps), an adequate supply of clean water must be supplied to the bearing for lubricating and cooling. Several of the following types of materials are used for internal water-lubricated

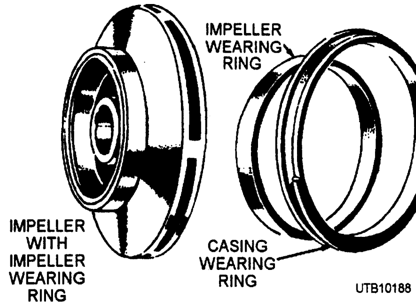

Figure 6-23.—Impeller, impeller wearing ring, and casing wearing ring for a centrifugal pump.

bearings-laminated phenolic material grade FBM (fabric-based Bakelite or Micarta), high lead content bronze, graphite bronze, and lignum vitae.

The condition of all types of internal water-lubricated bearings should be checked frequently to guard against excessive wear which can result in misalignment and shaft failure.

As for oil-lubricated sleeve or shell-type bearings, the bearing clearances should be measured following procedures described for the pump, and clearances should be maintained within the limits specified in the manufacturer's technical manual.

The clearance between the impeller wearing ring and the casing-wearing ring (fig. 6-23) must be maintained, as shown in the manufacturer's plans. When clearances exceed the specified figures, the wearing rings must be replaced. This replacement requires the complete disassembly of the pump. Information on disassembly of the unit, dimensions of the wearing rings, and reassembly of the pump is in the manufacturer's technical manual. (Wearing rings are located on the main feed pump, as shown in figure 6-24.)

When deciding whether the wearing rings need renewing, you must consider the capacity of the pump and the discharge pressure of the pump. On low-pressure pumps, the wearing ring diametrical clearance may be 0.015 to 0.030 inch more than the designed amount without any appreciable effect on the capacity of the pump. For pumps with a discharge pressure up to 75 psi, a wear of 0.030 to 0.050 inch is permissible.

The percentage of capacity loss with a 0.030-inch wearing ring clearance in excess of standard may be large with a small pump but comparatively small with a large pump. For high-pressure boiler feed pumps, the effect of increased wearing ring clearance is readily noticeable in the efficiency and maximum capacity of the pump. For high-pressure pumps, the wearing rings should be renewed when the clearance shown on the manufacturer's plans is exceeded by 100 percent. It is usually not necessary to renew wearing rings uniess the wear is at least 0.015 inch. If a pump has to be disassembled because of some internal trouble, you should check the wearing rings for clearance. Measure

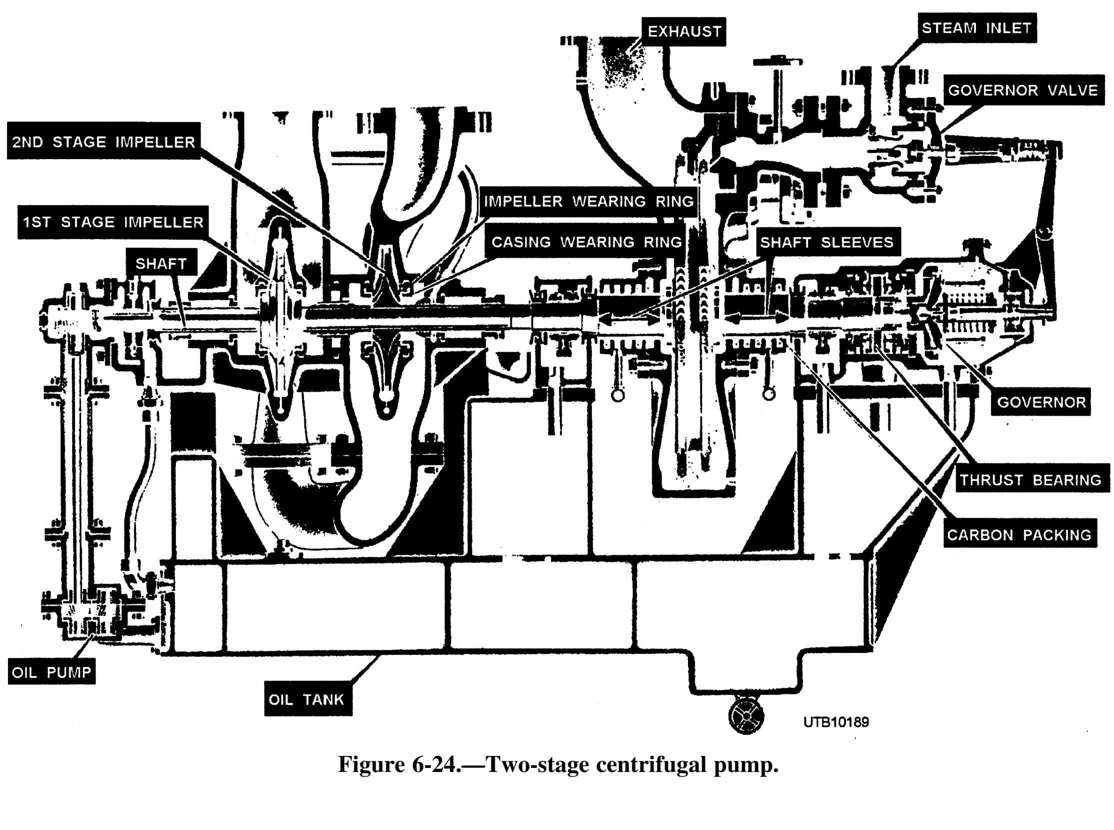

Figure 6-24.—Two-stage centrifugal pump.

the outside diameter of the impeller wearing ring with an outside micrometer and the inside diameter of the casing-wearing ring with an inside micrometer; the difference between the two diameters is the wearing ring diametrical clearance. By checking the wearing ring clearance with the maximum allowable clearance, you can decide whether to renew the rings before reassembling the pump.

The amount of work in disassembling the pump, the length of time the pump can be out of commission without affecting the command, and whether a repair shop or other repair activity are needed are some factors to consider when determining whether to renew wearing rings.

Wearing rings for most small pumps are carried aboard as part of the command's repair parts allowance. These may need only a slight amount of machining before they can be installed. For some pumps, such as main condensate and main feed booster pumps, spare rotors are carried. The new rotor can be installed and the old rotor sent to a repair activity for overhaul. Overhauling a rotor includes renewing the wearing rings, the bearings, and the shaft sleeve.

OPERATING TROUBLES.—Some of the operating troubles with centrifugal pumps and probable causes are given in table 6-1.

Table 6-1.—Centrifugal Pump Operating Troubles

Indication of Trouble	Cause
No liquid delivered	Pump needs primed Pump speed too low Discharge head too high Suction lift too high Impeller plugged up Incorrect pump rotation Impeller installed backward
Not enough liquid delivered	Suction pipe air leak Stuffing box air leak Pump speed too low Pump rotation incorrect Impeller installed backward Suction lift too high Suction line not completely submerged Impeller partially clogged Insufficient suction pressure (indicated by noise and fluctuating pressure when pumping hot or volatile liquids] Worn wearing rings, damaged impeller, worn stuffing box packing or worn seal, or sleeves need replaced
Low pressure	Pump speed low Air or gas in liquid Pump rotation incorrect Pump impeller installed backward Mechanical defects (see causes in not enough liquid delivered above)

Table 6-1.—Centrifugal Pump Operating Trouble—Continued

Pump works a while, and then fails to deliver	Air leak in the suction line Air leak in the stuffing box Stuffing box water seal plugged Suction line not completely submerged Suction lift too high
Stuffing box leaks excessively	Speed too high Misalignment Bent shaft Interference between rotating and stationary parts Worn journal bearings Worn or scored shaft sleeves at packing Rotor out of balance Sealng liquid contains dirt and grit, causing scoring
Short life of packing	Speed too high Misalignment Bent shaft Interference between rotating and stationary parts Worn journal bearings Packing installed wrong Scored shaft sleeves at packing Wrong type of packing Rotor out of balance Packing gland too tight Sealing liquid contains dirt and grit, causing scoring
Pump consumes too much power	Pump speed too high Specific gravity or liquid viscosity is higher than pump is designed to handle Rotor binding, shaft bent, stuffing box too tight, wearing rings worn, or misalignment System head is different than pump rating
Overheating or seizing	Speed too high Misalignment, bent shaft Rotor out of balance Excessive bearing temperature Bearing incorrectly installed Bearing rusted from water entering housing

When the pump fails to build up pressure and the discharge valve is open and the pump speed is increased, the procedure to use consists of four steps as follows:

1. Secure the pump.
2. Prime the pump and ensure that all the air is expelled through the air cocks on the pump casing.
3. Open all valves on the pump suction line.

4. Start the pump again. If the pump is electric-driven, be sure the pump is rotating in the correct direction. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged or an impeller broken. It is also possible that air is being drawn into the suction line or into the casing. If any of these conditions exist, stop the pump, try to find the source of the trouble, and correct it, if possible.

Air-Lift Pumps

Air-lift pumps are used entirely in well pumping. Unlike the pumps studied earlier, the air-lift pump needs no moving or rotating mechanism to produce liquid movement. Instead, the pump uses compressed air to move or lift the liquid.

The air-lift pump operates on the principle that water mixed with air has less weight, or is more buoyant, than water without air. When compressed air is introduced, a mixture of water and air is formed in one leg of the U-shaped pipe, as shown in figure 6-25. The solid column of water in the other leg now has greater weight or is exerting a greater static pressure than the column containing air. Thus the air-water column is forced upward until it discharges over the top of the U-shaped pipe.

In practice, of course, wells are not dug in a U-shape. Figure 6-26 shows a CENTRAL AIR-LIFT PUMP. Compressed air is led down an air pipe to a nozzle or foot piece submerged well below the water

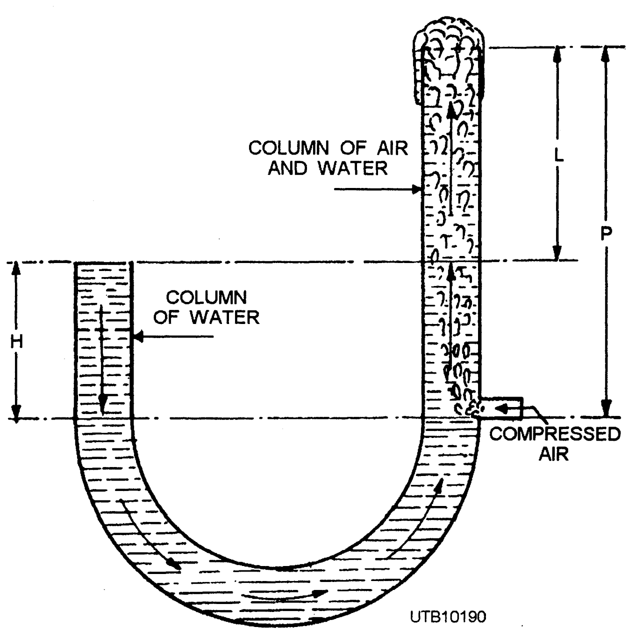

Figure 6-25.—Principles of an air-lift pump.

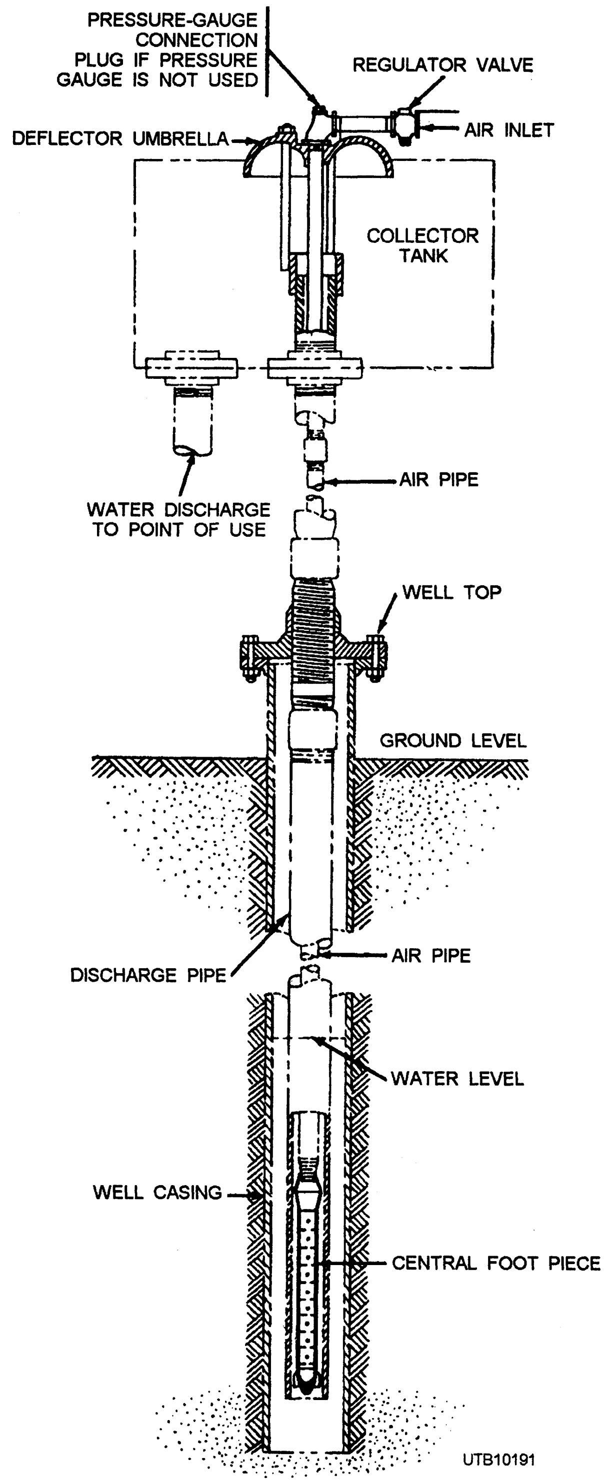

Figure 6-26.—Central air-lift pump.

level. Notice that the foot piece is suspended within a discharge pipe which, in turn, is contained within the well casing. Notice that the discharge pipe is open at the bottom, directly beneath the foot piece. When compressed air is discharged through the foot piece, a column or mixture of air is formed above the foot piece in the discharge pipe. The solid column of water in the well casing, resting high above the foot piece and discharge pipe inlet, now has greater weight or static pressure. This effect forces the air-water mixture upward in the discharge pipe where it is vented to the atmosphere through an open discharge outlet. In effect, the flow of water has a U-shape down the well casing, around the foot piece, and up the discharge pipe. The air-water discharge then strikes a separator or deflector that relieves the water of air bubbles and entrained air vapor. The discharge then settles in a collector tank.

The air-lift pump can deliver considerable quantities of water in the manner just described. The discharge pressure at which it is delivered, however, is relatively low. For this reason air-lift pumps cannot be used to discharge directly into a water distribution system. They do not develop sufficient pressure to distribute water horizontally above the ground for any appreciable distance, and the discharge can only be collected at the well for ground storage.

The capacity of the air-lift pump depends largely on the percentage of submergence of the foot piece; that is, the greater the submergence of the foot piece below the water level in the discharge pipe, the greater the volume (column) of water the pump can deliver per unit of time. However, the deeper the foot piece is submerged, the greater the compressed air pressure must be to lift the column of water. In other words, a higher column of water (in the discharge pipe) above the foot piece exerts a greater weight or pressure at the foot piece. The greater the static water pressure at the foot piece, the greater the air pressure must be to infuse air with the water.

Starting air pressure is always greater than working air pressure. When the pump is started, the static (at rest) level of water is drawn down somewhat to a pumping or working level. In effect, the column of water above the foot piece is decreased or lowered, and this, in turn, decreases the air pressure required to infuse the water with air. In wells where the drawdown is rather large, the pump is sometimes equipped with an auxiliary air compressor, connected in series with the main compressor, for starting. Once the pump has been started and the pumping level reached, the auxiliary compressor is no longer required and is secured.

Air-lift pumps have a low discharge pressure and require more depth so the foot piece can submerge deep enough. Additionally, the entrained oxygen in air-lifted water tends to make it more corrosive. In spite of these drawbacks, air-lift pumps have several advantages especially their simplicity of construction and lack of maintenance problems. Particularly useful in emergencies for deep well pumping, air-lift pumps can be used to pump crooked wells and wells with sand and other impurities. They can also pump hot-water wells with ease.

In air-lift pump operation, compressed air has to be regulated correctly. The amount of compressed air should be the minimum needed to produce a continuous flow of water. Too little air results in water being discharged in spurts, or not at all. Too much air causes an increase in the volume of discharge but at lower discharge pressure. If air is increased still further, discharge volume begins to decrease.

The air-lift pump is so simple in design that nearly all operating and maintenance inspections and procedures relate to the air compressor, which is described later.

Jet Pumps

Pumps that use the rapid flow of a fluid to entrain another fluid and thereby move it from one place to another are jet pumps. A jet pump contains no moving parts.

Jet pumps are EJECTORS that use a jet of steam to entrain air, water, or other fluid, and EDUCTORS that use a flow of water to entrain and thereby pump water. The basic principles of operation of these two devices are identical. The basic principle of operation of a simple jet pump of the ejector type is shown in figure 6-27. Steam under pressure enters the chamber through pipe A, which is fitted with a nozzle, B. As the steam flows through the nozzle, the velocity of the steam is increased. The fluid in the chamber at point F, in front of the nozzle, is driven out of the pump through the discharge line by the force of the steam jet. The size of the discharge line increases gradually beyond the chamber to decrease the velocity of the discharge and thereby transform some of the velocity head into pressure head. As the steam jet forces some of the fluid from the chamber into the discharge line, pressure in the chamber is lowered and the pressure on the surface of the supply fluid forces fluid up through the inlet, D,

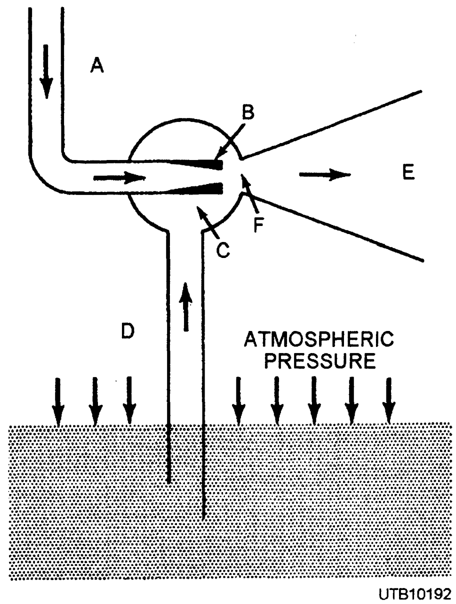

Figure 6-27.—Principle of operation of an ejector-type jet pump.

into the chamber and out through the discharge line. Thus the pumping action is established.

INSTALLATION OF PUMPS

From time to time, you will be installing prime movers, pumps, and air compressors. The secret of success in operating prime movers, pumps, and air compressors is their proper installation. That puts the success of their operation directly in your hands. If you do your job right and the equipment is properly installed, it should perform satisfactorily for a long time. Of course, proper care and maintenance are also essential for continued efficient operation; however, even with the most perfect care and maintenance, you will find it difficult or impossible to overcome faulty installation.

Since the procedures for installing prime movers, pumps, and air compressors are almost the same, only the basic steps of pump installation are discussed in this chapter. Remember that pumps, especially the centrifugal type, are built in many designs and for different purposes. Study the manufacturer's instruction manual for the equipment you are installing. Where specific directions or requirements are furnished, follow them.

When you receive a pump unit from supply, there are a few points to check. First, ensure it is the correct pump for the job by checking the nameplate data against that of the bill of material. Next, check the unit to ensure there are no missing or loose parts. If the unit has a preservative covering (exterior or interior), make certain it is removed before being installed.

When pumps are to be installed, the locations usually are determined in advance by higher authority and indicated on blueprints or sketches. However, you may have to decide where to put a pump. In most cases, place the pump as close as possible to the source of supply of water or other liquid, so the suction pipe is short and direct and the suction lift is comparatively low. With high-temperature liquids, a suction head is necessary. Place the pump where it can be readily inspected during operation, and see that headroom (a trap or ceiling opening) is there for the use of a crane, a hoist, or a tackle. If possible, select a dry place to protect the pump from the weather.

The foundation of a pump must be strong enough to absorb vibration and also to serve as a rigid support for the pump baseplate. A concrete foundation or a solid base is best. Foundation J-bolts are embedded in the concrete foundation according to a blueprint or a template. The bolts should be longer than needed (3/4 to 1 inch) to allow for shimming up the pump to make it level and for grouting under the pump base. A pipe sleeve, about 2 1/2 times the diameter of the bolt, allows for final positioning. If the bolt shown in figure 6-28 were 1 inch in diameter, a 2 1/2-inch pipe sleeve should be used. A small pump is normally aligned and the two major parts bolted together before leaving the factory. The parts normally do not require alignment after the pump has been set on the foundation. Be careful that you do not spring them out of alignment. Level the pump properly and secure it to the foundation. In setting the pump, you need a spirit level; place the level on the machined surfaces in two directions. To level, you may have to remove the top casing or bearing cover. If a large pump is shipped in sections, you have to align the water ends with the power ends after they have been placed on the foundation.

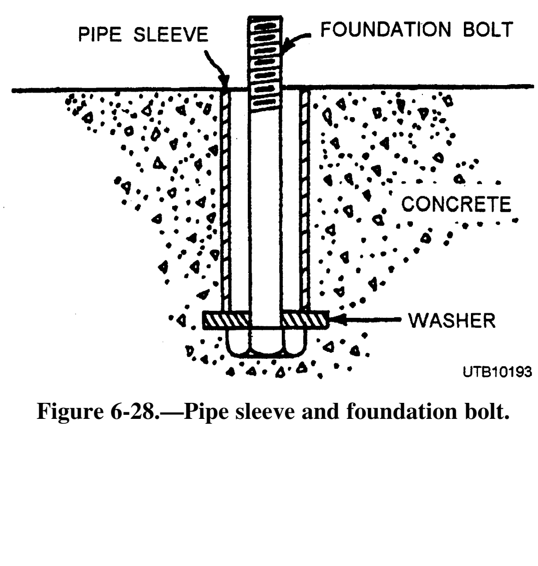

Figure 6-28.—Pipe sleeve and foundation bolt.

In leveling a pump unit, first use small metal wedges (fig. 6-29) and then place metal blocks and shims close to the foundation bolts. In each case, space the supports directly under the part carrying the most weight and close enough to give uniform support. Leave a gap of about 3/4 to 1 inch between the baseplate and the foundation for grouting with cement. (Grout is a mixture of cement, sand, and water, making up a thin mortar.) Figure 6-30 shows a baseplate of a pump unit grouted to the foundation, making angular alignment.

Adjust the supports or wedges until the shafts of the pump and the driver are level. Use a level to check the coupling faces and suction and discharge flanges to ensure that they are plumb and level. Correct the positions by adjusting the supports or wedges as required.

In addition to checking for parallel alignments, you should check the angular alignment between the pump shaft and the drive shaft. Insert a taper gauge or feeler at four points between the coupling faces, as shown in figure 6-31. The points should be spaced at 90-degree intervals around the coupling. When the measurements are all alike and the coupling faces are the same distance apart at the four points, the unit is in angular alignment. Correct any misalignment by adjusting the wedges or shims under the baseplate. Remember that an adjustment in one direction can disturb adjustments in another direction.

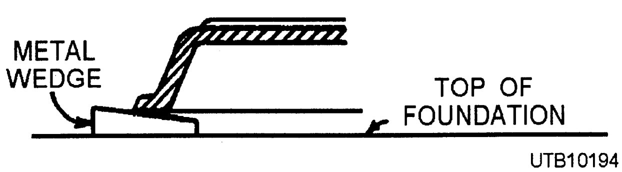

Figure 6-29.—Wedging a baseplate.

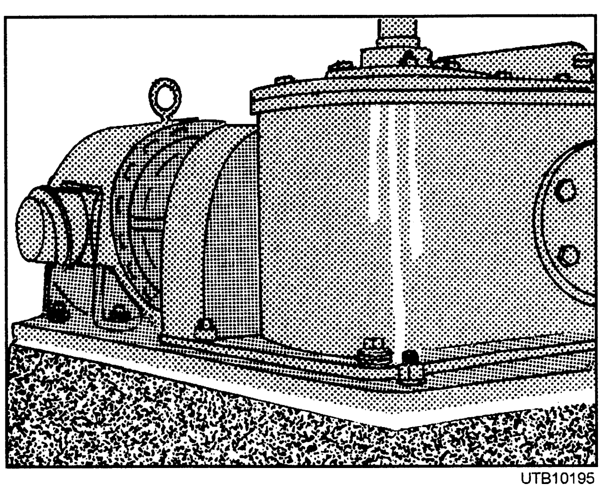

Figure 6-30.—Baseplate of a pump unit grouted to the foundation.

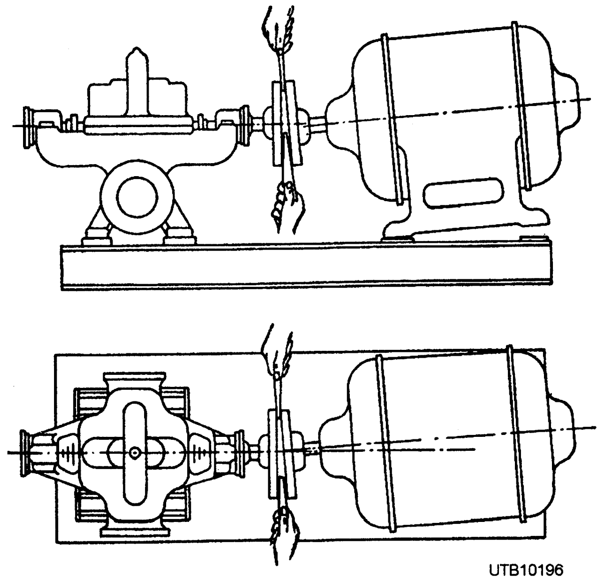

Figure 6-31.—Making angular alignment.

Many of the pumps used by the Navy are centrifugal pumps. Figure 6-32 shows a typical installation of a centrifugal pump. There are two types of assembly in which centrifugal pumps are delivered.

One group has the pump and the driver mounted on a common baseplate at the factory. The other group has only the pump mounted at the factory, so the driver must be positioned at the place of installation. In the former group, factory alignment may not have been maintained, as all baseplates are somewhat flexible. Therefore, you must realign the unit after it has been leveled on the foundation. To do this, first disconnect the coupling halves. Then follow the same alignment steps that have just been given. After completing these steps, reconnect the coupling and check it again for parallel and angular alignment. To install a centrifugal pump of the second group, you have a little extra work. After you have placed the baseplate with the pump on the foundation, you level, align, and bolt it. Next, place the driver on the baseplate according to the blueprints. Adjust the position of the driver and shim it up until the pump and driver half couplings are aligned. Then bolt it securely and proceed as in the other installation.

After you have correctly aligned the pump, tighten the foundation bolts evenly, but not too firmly. Then completely fill the baseplate with grout. Try to grout the leveling pieces, the shims, or the wedges in place. Foundation bolts should not be fully tightened until the grout has hardened, usually about 48 hours after pouring.

After the grout has set and the foundation bolts have been properly tightened, the pump should be

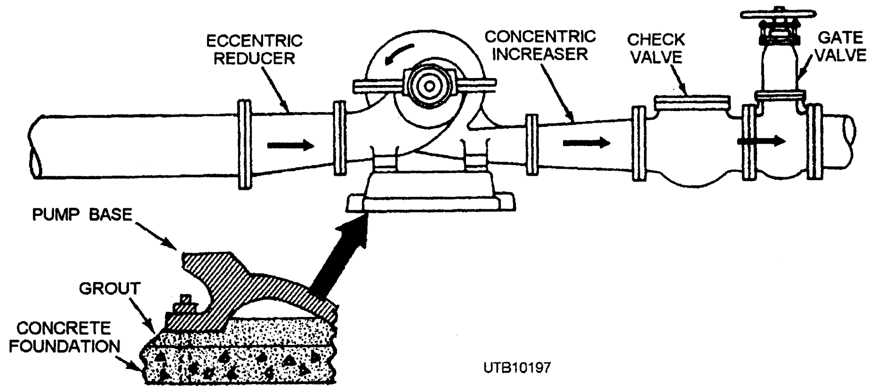

Figure 6-32.—Typical installation of a centrifugal pump.

checked again for parallel and angular alignment. You are now ready to connect the piping.

Piping

When installing the pump piping, be sure to observe the following precautions:

- Piping should always be run to the pump.
- Do not move the pump to the pipe. This could make final alignment impossible.
- Both the suction and discharge piping should be independently supported near the pump and properly aligned, so the strain is not transmitted to the pump when the flange bolts are tightened.
- Use pipe hangers or other supports at necessary intervals to provide support. When expansion joints are used in the piping system, they must be installed beyond the piping supports closest to the pump.
- Tie bolts should be used with expansion joints to prevent pipe strain. Do not install expansion joints next to the pump or in any way that would cause a strain on the pump, resulting from system pressure changes.
- It is usually advisable to increase the size of both the suction and the discharge pipes at the pump connections to decrease the loss of head from friction.
- Install piping as straight as possible, avoiding unnecessary bends. Where necessary, use 45-degree or long sweep 90-degree fittings to decrease friction losses.
- Make sure that all piping joints are airtight.
- Where flange joints are used, you must ensure that their inside diameters match properly.
- Remove burrs and sharp edges when marking up joints.
- Do not "spring" piping when marking connections.
- Provide for pipe expansion when hot fluids are to be pumped.

SUCTION PIPING.—When installing the suction piping, observe the precautions shown in figure 6-33. The sizing and installation of the suction

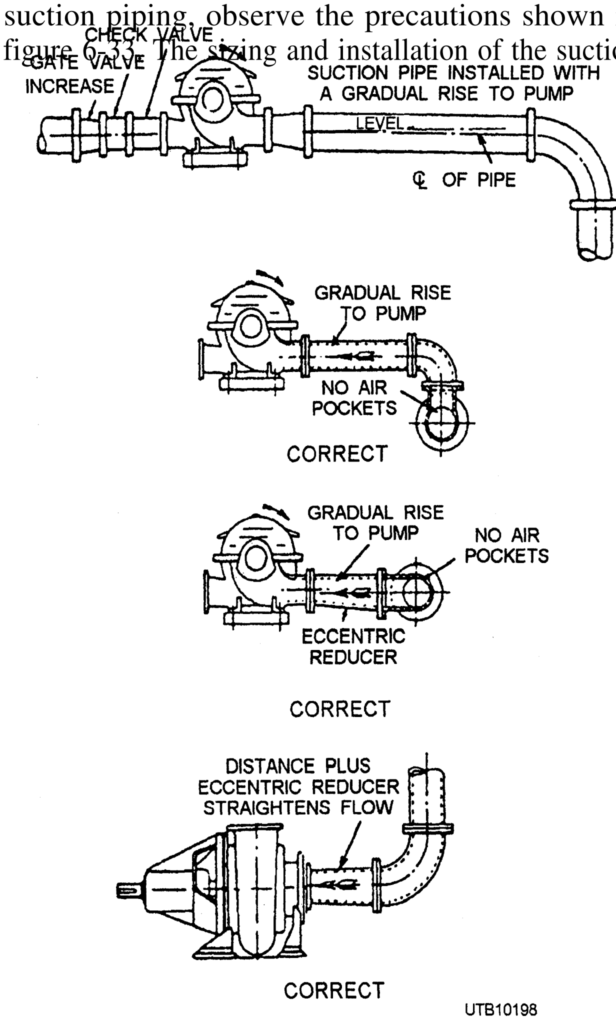

Figure 6-33.—Suction pipe installations.

piping are extremely important. The piping must be selected and installed, so pressure losses are minimized and sufficient liquid can flow into the pump when it is started and operated. Many net positive suction head (NPSH) problems can be directly attributed to improper suction piping systems.

Suction piping should be short in length, as direct as possible, and never smaller in diameter than the pump suction opening. If the suction pipe is short, the pipe diameter can be the same size as the suction opening. If longer suction pipe is required, pipes should be one or two sizes larger than the opening, depending on piping length.

Suction piping for horizontal double-suction pumps should not be installed with an elbow close to the suction flange of the pump. The only exception to this rule is when the elbow is in the vertical plane. A suction pipe of the same size as the suction nozzle approaching at any angle other than straight up or straight down has the elbow located ten pipe diameters from the suction flange of the pump. Vertically mounted pumps and other space limitations require special piping.

There is always an uneven turbulent flow around an elbow, and when it is in a position other than the vertical, it causes more liquid to enter one side of the impeller than the other (fig. 6-34). This results in high unequalled thrust loads that overheat the bearings and cause rapid wear in addition to affecting hydraulic performance.

When operating on a suction lift, you should ensure the suction pipe slopes upward to the pump nozzle. A horizontal suction line must have a gradual rise to the pump. Any high point in the pipe becomes filled with air and thus prevents proper operation of the pump. When reducing the piping to the suction opening diameter, use an eccentric reducer with the eccentric side down to avoid air pockets.

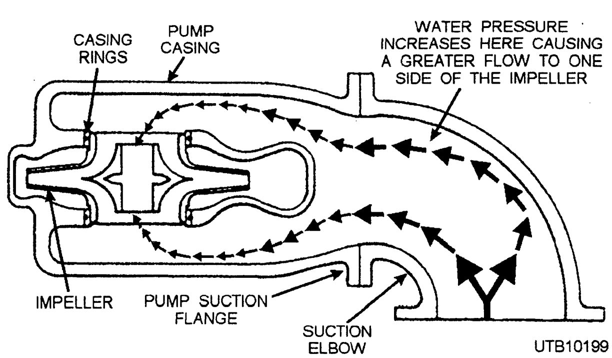

Figure 6-34.—Unbalanced loading of a double-suction impeller.

CAUTION

When operating on a suction lift, you should never use a straight taper reducer in a horizontal suction line, as it tends to form an air pocket in the top of the reducer and the pipe

To clean the pump liquid passage witnout dismantling the pump, bolt an increasing suction nozzle to the suction flange. If this is not done, a short section of pipe (Dutchman or spool piece), so designed that it can be readily dropped out of the line, can be installed adjacent to the suction flange. With this arrangement, any matter clogging the impeller is accessible by removing the nozzle (or pipe section).

DISCHARGE PIPING.—If the discharge piping is short, the pipe diameter can be the same size as the discharge opening. If the piping is long, the pipe diameter should be one or two sizes larger than the discharge opening. On long, horizontal runs, it is desirable to maintain as even a grade as possible. Avoid high spots, such as loops, that collect air and throttle the system or lead to erratic pumping.

VALVES IN PIPING.—When installing valves in the suction piping, observe the following precautions:

If the pump is operating under static suction lift conditions, a foot valve should be installed in the suction line to avoid the necessity of priming each time the pump is started. This valve should be of the flapper type, rather than the multiple spring type, and sized to avoid excessive friction in the suction line. (Under all other conditions, a check valve, if used, should be installed in the discharge line.)

When foot valves are used or where there are other possibilities of "water hammer," close the discharge valve slowly before shutting down the pump.

When two or more pumps are connected to the same suction line, install gate valves so any of the pumps can be isolated from the line. Gate valves should be installed on the suction side of all pumps with a positive pressure for maintenance purposes. Install gate valves with horizontal stems to avoid air pockets. Globe valves should not be used, particularly where NPSH is critical.

The pump must never be throttled by the use of a valve on the suction side of the pump. Suction valves. should be used only to isolate the pump for maintenance purposes and should always be installed in positions to avoid air pockets.

When installing valves in the discharge piping, you should install a check valve and gate valve in the discharge piping. The check valve, placed between the pump and the gate valve, protects the pump from excessive back pressure and prevents liquid from running back through the pump in case of power failure. The gate valve is used in priming, starting, and shutting down the pump.

PRESSURE GAUGES.—Properly sized pressure gauges should be installed in both the suction and the discharge nozzles in the gauge taps. The gauges enable the operator to observe the operation of the pump easily and also to determine if the pump is operating according to the performance curve. If cavitation, vapor binding, or other unstable operation occurs, widely fluctuating discharge pressure will occur.

Stuffing Box

Contaminants in the pumped liquid must not enter the packing space. These contaminants can cause severe abrasion or corrosion of the shaft, or shaft sleeve, and rapid packing deterioration; they can even plug the stuffing box flushing and lubrication system. The stuffing box must be supplied at all times with a source of clean, clear liquid to flush and lubricate the packing. The most important consideration is to establish optimum flushing pressure to eliminate contaminants from the packing. If this pressure is too low, the fluid being pumped may enter the stuffing box. If the pressure is too high, excessive packing wear can result; also, extreme heat may develop in the shaft, causing higher bearing temperatures. The most desirable condition, therefore, is to use the lowest possible flushing pressure that the operating conditions will permit. If the pump system pressure conditions vary during the day, the packing problem becomes difficult. Consideration should be given to using a mechanical seal. (See "Mechanical Seals" below.)

One recommended method to minimize error in regulating flushing is a "controlled pressure system" (fig. 6-35). Most important is the pressure-reducing valve adjusted to a valve slightly exceeding the maximum stuffing box operating pressure (assuming it is reasonably constant). A flow-indicating device serves to indicate a failing of the bottom packing rings, allowing leakage into the pump. With this arrangement, the packing gland must be tightened only against the lowest necessary pressure. Longer packing life is possible with the "controlled pressure system," if it is properly installed and operated.

The actual stuffing box operating pressure may be obtained by installing a pressure gauge on the box. This is done with an extra seal cage temporarily replacing the two rings of packing in the bottom of the box to obtain accurate gauge readings. Take gauge readings with the pump running under various head and capacity conditions. Then set the pressure of flushing or lubricating liquid at a value of 5 to 10 psi above the maximum expected stuffing box operating pressure.

Even under the best conditions, a properly packed stuffing box should be watched closely. When pressure conditions change slightly, there is a resultant change in packing (seating) which should be compensated by a change in gland adjustment. Consideration should also be given to the lubrication pressure. A wide variation in pressure indicates a need for a mechanical seal.

Packing

Standard pumps are normally packed before shipment. If the pump is installed within 60 days after shipment, the packing should be in good condition with a sufficient supply of lubrication. If the pump is stored for a longer period of time, it may become necessary to repack the stuffing box. In all cases, you should inspect the packing before starting the pump.

INTERNAL LIQUID LUIBRICATION.— Pumped liquid may be used to lubricate the packing when the following conditions exist:

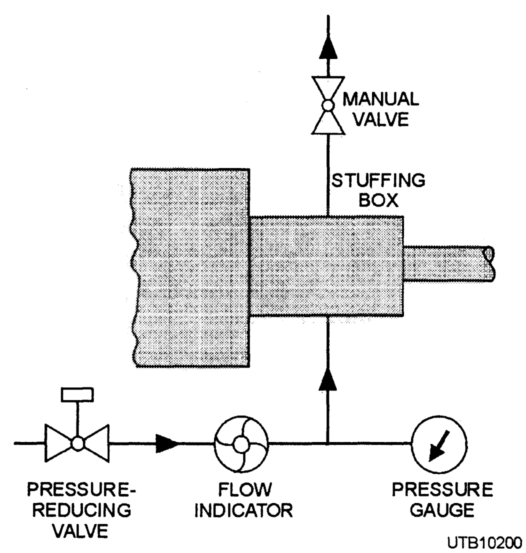

Figure 6-35.—Controlled pressure system for stuffing box.

The liquid is clean, free from sediment and chemical precipitation, and compatible with seal materials.

- The temperature is above 32°F and below 160°F.
- The suction pressure is below 75 psig.
- The liquid has adequate lubricating qualities.
- The liquid is nontoxic and nonvolatile.

EXTERNAL LIQUID LUBRICATION.—When the liquid being pumped contains solids or is otherwise not compatible with packing materials, an outside supply of seal liquid should be furnished. In general, external-injection liquid (from an outside source) is required when the following conditions exist.

- Liquid being pumped contains dirt, grit, or other impurities.
- The temperature of the pumped liquid is below 32°F or above 160°F.
- The liquid being pumped has nonlubricating properties.
- The liquid is toxic or volatile.
- The suction pressure is above 75 psig, vacuum, or high lift.

Mechanical seals are preferred over packing on some applications because of better sealing qualities and longer serviceability. Leakage is eliminated when a seal is properly installed, and normal life is much greater than that of packing on similar applications. A mechanical shaft seal is supplied in place of a packed stuffing box when specifically requested. The change from packing to an alternate arrangement may be made in the field. Conversion kits may be ordered from the manufacturer.

SINGLE SEAL.—Pumps containing single mechanical seals normally use pumped liquid to lubricate the seal faces. This method is preferred when the pumped liquid is neither abrasive nor corrosive. If the liquid being pumped is not suitable, an external flush should be provided. (See "External Liquid Lubrication" above.)

DOUBLE SEAL.—A double mechanical seal consists of two single seals mounted back to back and a suitable sealing liquid that is introduced into the seal chamber. The sealing liquid (preferably clear water) is injected into the box at a higher pressure than exists at the entrance to the seal cavity on the pump side. The pressure differential isolates the sealing faces from the pumped liquid. Double mechanical seals are normally preferred in pumps handling sewage, slurries, or any other solids suspended in the pumped liquid.

Sealing liquid that is introduced through the tap in the seal cavity provides lubrication for the double seal. The sealing liquid pressure must always be higher than the pressure on the seal closest to the suction side. If sufficient sealing pressure is not maintained, the pressure within the pump can force open the lower seal and allow the pumped liquid to enter the box. This can damage the seals.

Two methods are used to provide sealing liquid to the stuffing box. The first method uses a pressure line installed from a tap on the discharge nozzle to the tap in the stuffing box cartridge. A filter is installed in the line to trap the solid particles. The filter must be capable of screening out all particles above 25 microns in size. Since the liquid is bypassed from the high-pressure (discharge) side of the pump and dead-ended in the stuffing box cartridge, there are no problems in maintaining a sufficient pressure differential, provided the filter is not clogged. The second method uses clear, clean water supplied from an external source. City water can be used if there is an air break between the water supply and the water being provided to the pump. Various municipal ordinances require this break to prevent contamination of the city water supply.

PUMP MAINTENANCE

Operating conditions vary so widely that to recommend one schedule of preventive maintenance for all centrifugal pumps is not possible. Yet some sort of regular inspection must be planned and followed. You should maintain a permanent record of the periodic inspections and maintenance performed on a pump. This procedure will assist you in keeping the pump in good working condition and prevent costly breakdowns.

One of the best rules to follow in the proper maintenance of a centrifugal pump is to keep a record of actual operating hours. Then, after a predetermined period of operation has elapsed, the pump should be given a thorough inspection. The length of this operating period varies with different applications and can only be determined from experience. New equipment, however, should be examined after a relatively short period of operation. The next inspection period can be lengthened somewhat. This system can be followed until a maximum period of operation is reached which should be considered the operating schedule between inspections.

Bearing Lubrication—Grease

Grease-lubricated bearings are packed with grease at the factory and ordinarily require no attention before starting, provided the pump has been stored in a clean, dry place before its operation. The bearings should be watched the first hour or so after the pump has been started to see that they are operating properly.

The importance of proper lubrication cannot be overemphasized. It is difficult to say how often a bearing should be greased, since that depends on the conditions of operation. It is important to add 1 ounce of grease at regular intervals, but it is equally important to avoid adding too much grease. For average operating conditions, it is recommended that 1 ounce of grease be added at intervals of 3 to 6 months, and only clean grease should be used. It is always best if the unit can be stopped while the grease is added to avoid overloading.

> **CAUTION**
>
> Excess grease is the most common cause of overheating.

The bearing frame should be kept clean, since contamination of foreign matter that may get into the housing can destroy the bearings within a short period of time. When cleaning bearings, use a bearing or an industrial cleaning solvent. Do not use gasoline. Use a lint-free cloth. Do not use waste rags.

A regular bearing grease should be used, but a standard commercial vaseline can be substituted if necessary. Do not use graphite. A No. 1 or a No. 2 grease is generally satisfactory for operation at ordinary temperatures; the lighter grease should be used for operation at high speed or at low room temperature.

Mineral grease with a soda soap base is recommended. Grease, made from animal or vegetable oils, is not recommended because of the danger of deterioration and the forming of acid. Most of the leading oil companies have special types of bearing grease that are satisfactory. For specific recommendations, consult the manufacturer's manual.

The maximum desirable operating temperature for bearings is 180°F. Should the temperature of the bearing frame rise above 180°F, the pump should be shut down to determine the cause. Grease-lubricated bearings should not be used where temperature of the pumped liquid exceeds 350°F.

> **CAUTION**
>
> A bearing frame that feels hot to the touch is not necessarily running hot. Check the temperature with an accurate measuring device to be sure.

Bearing Lubrication-Oil

An oil-lubricated pump normally has an oiling ring. In these, the oil is picked up from the reservoir by a rotating oil ring and deposited on the shaft and the bearings inside the bearing housing. Some may have an oil slinger that creates a shower of fine droplets of oil over the entire interior of the bearing cavity.

After the pump has been installed, flush the bearing housing to remove dirt, grit, and other impurities that may have entered the bearing housing during shipment or erection. Then refill the bearing housing with proper lubricant. The oil level to be maintained is shown by a line in the sight glass or oil level indicator.

Lubricating oils can be furnished by any of the major oil companies, and it is the responsibility of the oil vendor to supply suitable lubricants. Experience has shown that oils meeting the following specifications provide satisfactory lubrication.

• Saybolt viscosity at 100°F	150 SSU-200 SSU
• Saybolt viscosity at 210°F	43 SSU
• Viscosity index, minimum	95
• API gravity	28-33
• Pour point, maximum	20°F
• Flash point, minimum	390°F
• Additives	Rust and oxidation inhibitors

CAUTION

Oils from different suppliers should not be mixed. The oil must be well-refined, good grade, straight cut, and filtered mineral oil. It must be free from water, sediment, resin, soaps, acid, and fillers of any kind. It should also be nonfoaming with a viscosity of about 150 to 200 SSU at 100°F (approximately SAE-20).

In installations with moderate temperature changes, humidity, and dirt, the oil should be changed after approximately 160 hours of operation. The oil should be inspected at this time to determine the operating period before the next oil change. Oil change periods may be increased from 2,000 to 4,000 hours based on an 8,000-hour year. Check the oil frequently for moisture, dirt, or signs of "breakdown."

CAUTION

DO NOT OVER OIL; THIS CAUSES THE BEARINGS TO RUN HOT. THE MAXIMUM DESIRABLE OPERATING TEMPERATURE FOR BEARINGS IS 180°F. SHOULD THE TEMPERATURE OF THE BEARING FRAME EXCEED 180°F, SHUT DOWN THE PUMP TO DETERMINE THE CAUSE!

Stuffing Box

The standard stuffing box consists of rings of packing, a seal cage, and a gland. A shaft sleeve that extends through the box and under the gland is normally provided to protect the shaft.

A tapped hole is supplied in the stuffing box directly over the seal cage to introduce a clean, clear sealing medium. The stuffing box must be supplied at all times with sealing liquid at a high enough pressure to keep the box free from foreign matter, which would quickly destroy the packing and score the shaft sleeve.

Only a sufficient volume of sealing liquid to create a definite direction of flow from the stuffing box inward to the pump casing is required, but the pressure is important. Apply sealing water at a rate of 0.5 to 1.0 gpm and at 5 to 10 psi above the stuffing box operating pressure.

Piping that supplies sealing liquid to the stuffing box must be sized to supply a sufficient volume of water at the required pressure, based on the location of the pump (or pumps) with respect to the liquid source. A small pipe can be used for the connection to the stuffing box. A valve should be installed to adjust and regulate sealing liquid, and a gauge should be installed to check the pressure to the box.

External sealing liquid should be adjusted to the point where the packing runs only slightly warm with a slow drip from the stuffing box. Excessive pressure from an external source can be destructive to packing. More pressure is required, however, for abrasive slurries than for clear liquids. Examination of the leakage will indicate whether it is necessary to increase external pressure. If slurry is present in the leakage, increase the pressure until only clear liquid drips from the box. If the drippage is corrosive or may be harmful to personnel, it should be collected and piped away.

A common error is to open the external piping valve wide and then control the drippage by tightening the packing gland. Actually, a combination of both adjustments is essential to arrive at the optimum condition. The life of the packing and the sleeve depends on this careful control more than any other factor.

GREASE LUBRICATION.—Pump stuffing boxes are also suitable for grease lubrication. Several types of grease lubricators are available. When you use a grease lubricator, grease pressure to the stuffing box should be equal to the pump discharge pressure.

PACKING.—All pumps are packed before shipment, unless otherwise requested. The packing used is of the highest grade material. Before the pump is put into operation, check the condition of the packing. If the pump is installed within 60 days after shipment, the packing should be in good condition with a sufficient supply of lubrication. If the pump is stored for a longer period, it may become necessary to repack the stuffing box. In all cases, inspect the packing before starting the pump.

The standard packing is made of a soft, square asbestos material that is impregnated with oil and graphite. A soft, well-lubricated packing reduces stuffing box resistance and prevents excessive wear on the shaft, or shaft sleeve. Many brands of packing on the market have the desired qualities. For specific recommendations, consult the manufacturer's manual.

When a pump with fiber packing is first started, it is advisable to have the packing slightly loose without causing an air leak. As the pump breaks in, tighten the gland bolts evenly. The gland should never be drawn to the point where packing is compressed too tightly, and no leakage occurs. This causes the packing to burn the shaft, or shaft sleeve, to be scored, and prevents liquid from circulating through the stuffing box and cooling the packing. The stuffing box is improperly packed or adjusted when friction in the box prevents the rotating element from being turned by hand. A packed stuffing box that is operating properly should run lukewarm with a slow drip of sealing liquid. After the pump has been in operation for some time and the packing has been completely run-in, drippage from the stuffing box should be at least 40 to 60 drops per minute. This indicates that there is proper packing, that the shaft sleeve is adequately lubricated, and that it is cooled properly.

CAUTION

Eccentric operation of the shaft, or shaft sleeve, through the packing could result in excess leakage. Correction of this defect is extremely important.

Packing should be checked frequently and replaced as service indicates. Six months might be a reasonable expected life, depending on operating conditions. It is impossible to furnish an exact prediction. A packing tool may be used to remove old packing from the stuffing box. Never reuse old and lifeless packing or merely add some new rings. Make sure the stuffing box is thoroughly cleaned before new packing is installed. Also, check the condition of the shaft, or shaft sleeve, for possible scoring or eccentricity, making replacements as necessary.

New packing should be placed carefully into the stuffing box. If molded rings are used, the rings should be opened sideways and the joints pushed into the stuffing box first. The rings are installed one at a time, each ring is seated firmly, and the joints are staggered so they are not in line. The joints should be kept toward the upper side of the shaft about a 90-degree angle from each preceding joint.

If coil packing is used, cut one ring to accurate size with either a butt or mitered joint. An accurately cut butt joint is superior to a poor fitting mitered joint. Fit the ring over the shaft to assure proper length. Then remove and cut all other rings to the size of this first sample. When the rings are placed around the shaft, you should form a tight joint. Place the first ring in the bottom of the stuffing box. Then install each succeeding ring, staggering the joints as described above, making sure each ring is firmly seated.

Make sure the seal cage is properly located in the stuffing box under the sealing water inlet. The function of the seal cage is to establish a liquid seal around the shaft, to prevent leakage of air through the stuffing box, and to lubricate the packing. If it is not properly located, it serves no useful purpose.

Mechanical Shaft Seals

A mechanical shaft seal is supplied in place of a packed stuffing box when specifically requested. Mechanical seals are preferred over packing on some applications because they have better sealing qualities and longer serviceability. Leakage is eliminated when a seal is properly installed, and normally, the life of the seal is much greater than that of packing on similar applications.

General instructions for operation of the various mechanical sealing arrangements are included below. It is not feasible to include detailed instructions for all mechanical seals in this chapter because of the almost unlimited number of possible combinations and arrangements. For more information, refer to the manufacturer's instructions.

Mechanical seals are precision products and should be treated with care. Use special care when handling seals. Clean oil and clean parts are essential to prevent scratching the finely lapped sealing faces. Even light surface scratches on these faces could result in leaky seals. Normally, mechanical seals require no adjustment or maintenance except routine replacement of worn or broken parts.

A mechanical seal that has been used should not be placed back into service until the sealing faces have been replaced or relapped. (Relapping is generally economical only in seals that are 2 inches and greater in size.)

Four important rules that should always be followed for optimum seal life are as follows:

1. Keep the seal faces as clean as possible.
2. Keep the seal as cool as possible.
3. Ensure the seal always has proper lubrication.

4. If the seal is lubricated with filtered fluid, clean the filter frequently.

Maintenance Timetable

Equipment cannot operate well without proper care. To keep the pump at top efficiency, follow the recommended installation and servicing procedures outlined in the manufacturer's manual. Table 6-2 is a recommended maintenance timetable for use in keeping a pump at maximum operating capacity with a minimum amount of downtime.

Q5. The locations in a pump where fluid enters (suction) and leaves (discharge) are known by what other term?

Table 6-2.—Maintenance Timetable

Every Month	Check bearing temperature with a thermometer, not by hand. If bearings are running hot (over 180°F), it may be the result of too much lubricant. If changing the lubricant does not correct the condition, disassemble and inspect the bearings.
Every 3 Months	Check grease-lubricated bearings for saponification. This condition is usually incurred by the infiltration of water or other fluid past the bearing shaft seals and can be noticed immediately upon inspection, since it gives the grease a whitish color. Wash out the bearings with a clean industrial solvent and replace the grease with the proper type as recommended.
Every 6 Months	Check the packing and replace if necessary. Use the grade recommended. Be sure the seal cages are centered in the stuffing box at the entrance of the stuffing box piping connection. Check shaft or shaft sleeve for scoring. Scoring accelerates packing wear. Check alignment of pump and motor. Shim up units if necessary. If misalignment recurs frequently, inspect the entire piping system. Unbolt piping at suction and discharge flanges to see if it springs away, thereby indicating strain on the casing. Inspect all piping supports for soundness and effective support of load.
Every Year	Remove the rotating element. Inspect thoroughly for wear, and order replacement parts if necessary. Check wearing clearances. Remove any deposit or scaling. Clean out stuffing box piping. Measure total dynamic suction and discharge head as a test of pipe connection. Record the figures and compare them with the figures of the last test. This is important especially where the fluid being pumped tends to form a deposit on internal surfaces. Inspect foot valves and check valves, especially the check valve which safeguards against water hammer when the pump stops. A faulty foot or check valve will reflect also in poor performance of the pump.

Between regular maintenance inspections, be alert for signs of motor or pump trouble. Common symptoms are listed in table 6-3. Correct any trouble immediately and AVOID COSTLY REPAIR AND SHUTDOWN.

Q6. What is total discharge head?

Q7. The amount of suction lift a pump can provide is determined by what three factors?

Q8. What are the five categories of pumps?

Q9. A rotary pump is classified as what type of pump?

Q10. What are the types of rotary pumps?

Q11. Most reciprocating pumps used in the Navy are of what four types?

Q12. What is the only moving part in a centrifugal pump?

Q13. When the velocity of a fluid in a pump increases, what happens to the pressure head?

Q14. What pumps are used exclusively for well pumping?

Q15. When an elbow is installed horizontally in suction piping, what happens to the liquid entering the pump?

Q16. Why should you avoid high spots, such as loops, in discharge piping?

Q17. Widely fluctuating discharge pressure gauge indicates what type of problem?

Q18. On grease-lubricated bearings, what is the most common problem caused by excessive grease?

Q19. What advantage does a mechanical shaft seal have over packing?

Q20. Using table 6-2, how often should you inspect the packing on a pump?

Q21. Using table 6-2, removal and inspection of the rotating elements of a pump should be accomplished how often?

AIR COMPRESSORS

LEARNING OBJECTIVE: *Recognize types of air compressor components, accessories, systems, operation of these systems, and maintenance procedures.*

Air compressors are devices or machines that compress air. In compression, air at a normal atmospheric temperature is taken in and sqeezed or pressed by a moving element within a confined space. The volume of air is thus reduced, but the pressure, or force, of the volume of air exerted has increased considerably. Thus the air develops energy or power that can be put to some useful purpose in other machines. The compressed air need not be put to work immediately but can be stored in tanks to preserve and maintain its pressure.

Compressed air can be taken from storage bottles or flasks and used to start diesel engines; that is, the compressed air is introduced into the diesel cylinders where, by its pressure, it forces the pistons to reciprocate until ignition temperature is reached. We have seen how compressed air forces water to rise in wells. Air compressors also drive, or power, a wide variety of pneumatic tools in construction work. The types of air compressors include reciprocating, centrifugal, and rotary; however, only reciprocating compressors are discussed in the following paragraphs. In basic design and function, these compressors are similar to the pumps with the same names. In fact, air compressors are sometimes referred to as air pumps. Rather than discharging liquid at relatively high pressure, air compressors discharge air (which is considered a fluid) at high pressure. Like pumps, compressors require some external source of mechanical power to do this work. Prime movers for air compressors may be electric motors, internal combustion engines, steam turbines, and so on. The majority of air compressors used throughout the Navy are driven by electric motors.

RECIPROCATING AIR COMPRESSORS

One of the most commonly used air compressors in the naval service is the reciprocating air compressor. It compresses air in the same manner as a diesel engine. A reciprocating piston alternately draws in and then compresses the trapped air in a cylinder. Since there is no internal combustion, the cycle of the reciprocating air compressor is reduced or simplified to two strokes-suction (intake) and compression. Instead of operating the valves by cam action, as in internal combustion engines, the intake and discharge valves of the reciprocating air compressor operate on the principle of differential pressure overcoming spring tension,

Table 6-3.—Troubleshooting

1. Lack of prime.	Fill pump and suction pipe completely with liquid.
2. Loss of prime.	Check for leaks in suction pipe joints and fittings; vent casing to remove accumulated air.
3. Suction lift too high.	If no obstruction at inlet, check for pipe friction losses. However, static lift may be too great. Measure with mercury column or vacuum gauge while pump operates. If static lift is too high, liquid to pump must be raised or pump must be lowered.
4. Discharge head too high.	Check pipe friction losses. Large piping may correct condition. Check that valves are open.
5. Speed too low.	Check if motor is directly across the line and receiving full voltage. Or frequency may be to low; motor may have an open phase.
6. Wrong direction of rotation.	Check motor rotation with directional arrow on pump casing.
7. Impeller completely plugged.	Dismantle pump and clean impeller.
Not Enough Liquid Delivered	
8. Air leaks in suction piping.	If liquid pumped is water or nonexplosive, and explosive gas or dust is not present, test flanges for leakage with flame or match. For such liquids as gasoline; the suction line can be tested by shutting off or plugging the inlet and putting the line under pressure. A gauge will indicate a leak if pressure drops.
9. Air leaks in stuffing box.	Increase seal lubricant pressure to above atmosphere.
10. Speed too low.	See item 5.
11. Discharge head too high.	See item 4.
12. Suction lift too high.	See item 3.
13. Impeller partially plugged.	See item 7.
14. Cavitation; insufficient NPSH (depending installation).	a. Increase positive suction head on pump by lowering pump. b. Subcool suction piping at inlet to lower entering liquid temperature. c. Pressurized suction vessel.
15. Defective impeller.	Inspect impeller, bearings, and shaft. Replace if damaged or vane sections badly eroded.
16. Defective packing.	Replace packing and sleeves if badly worn.
No Liquid Delivered	
17. Foot valve too small or partially obstructed.	Area through ports of valve should be at least as large as area of suction pipe-preferably 1 1/2 times. If strainer is used, net clear area should be three to four times area of suction pipe
18. Suction inlet not immersed deep enough.	If inlet cannot be lowered or if eddies through which air is sucked persist when it is lowered, chain a board to suction pipe. It will be drawn into eddies, smothering the vortex.
19. Wrong direction of rotation.	Symptoms are an overloaded drive and about 1/3 rated capacity from pump. Compare rotation of motor with directional arrow on pump casing.
20. Too small impeller diameter (probable cause if none of the above).	Check with factory to see if larger impeller can be used; otherwise, cut pipe losses or increase speed-or both, as needed. Be careful not to overload drive

Table 6-3.—Troubleshooting—Continued

Not Enough Pressure	
21. Speed too low.	See item 5.
22. Air leaks in suction piping.	See item 8.
23. Mechanical defects.	See items 15, 16, and 17.
24. Obstruction in liquid passages.	Dismantle pump and inspect passages of impeller and casing. Remove obstructions.
25. Air or gases in liquid (tested in laboratory) reducing pressure on liquid to pressure in the suction line. Watch for bubble formation.	May be possible to overrate pump to point where it will provide adequate pressure despite condition. Better to provide gas separation chamber on suction line near pump, and periodically exhaust accumulated gas. See item 14.
26. Too small impeller diameter. (probable cause if none of the above.)	See item 20.
Pump Operates For Short Time, Then Stops	
27. Incomplete priming.	Free pump, piping, and valves of all air. If high points in suction line prevent this, they need correcting.
28. Suction lift too high.	See item 3.
29. Air leaks in suction piping.	See item 8.
30. Air leaks in stuffing box.	See item 9.
3 1. Air or gases in liquid.	See item 25.
32. Head lower than rating; thereby pumping too much liquid.	Machine impeller's OD to size advised by factory.
33. Cavitation.	See item 14.
34. Mechanical defects.	See item 15, 16, and 17.
35. Suction inlet not immersed enough.	See item 18.
36. Liquid heavier (in viscosity or specific gravity) than allowed for.	Use larger driver. Consult factory for recommended size. Test liquid for viscosity and specific gravity.
37. Wrong direction of rotation.	See item 6.
38. Stuffing boxes too tight.	Release gland pressure. Tighten reasonably. If sealing liquid does not flow while pump operates, replace packing. If packing is wearing too quickly, replace scored shaft sleeves and keep liquid seeping for lubrication.
39. Casing distorted by excessive strains from suction or discharge piping.	Check alignment. Examine pump for friction between impeller and casing. Replace damaged parts.
40. Shaft bent due to damage.	Check deflection of rotor by turning on bearing journals. Total indicator run-off should not exceed 0.002 on shaft and 0.004 inch on impeller wearing surface.
41. Mechanical failure of critical pump parts.	Check bearing and impeller for damage. Any irregularity in any of these parts will cause a drag on shaft.
42. Misalignment.	Realign pump and driver.
43. Speed may be too high.	Check voltage on motor.
44. Electrical defects.	The voltage and frequency of the electric current may be lower than that for which motor was built; or there may be defects in motor. The motor may not be ventilated properly due to a poor location.
45. Mechanical defects in turbine, engine, or other type of drive exclusive of motor.	If trouble cannot be located, consult factory.

much the same as the check valves operate in reciprocating pumps. The suction stroke occurs as the piston moves downward to create a partial vacuum and causes the intake valve to open. Air, at normal atmospheric pressure, is then drawn into the cylinder, as the piston continues downward. When the piston moves on the upward stroke, the intake valve closes. The trapped air is compressed as the piston continues upward. As the piston reaches the top of its compression' stroke, the air pressure developed overcomes the resistance of the spring-loaded discharge valve.

The discharge valve opens momentarily and the compressed air charge then passes into the discharge line. When higher pressure is desired, more cylinders or stages may be provided (fig. 6-36). The discharge of the first stage is led to the intake of the second stage, and so on. The principle here is almost the same as that in the multistage impeller arrangements used to increase the discharge pressure on centrifugal pumps. Figure 6-37 shows a more detailed view of a two-stage reciprocating air compressor. You can see that the second-stage cylinder is noticeably smaller than the first. If there were more cylinders, each would be smaller. This is the compression process, whereby the volume of the air charge is continually reduced as it passes from one stage to the next; and, at the same time, the pressure becomes greater. Figure 6-38 shows an alternate type of low-pressure air compressor.

COMPRESSOR COMPONENTS

The pistons are either TRUNK PISTONS or DIFFERENTIAL PISTONS. Trunk pistons, as shown in view A, figure 6-39, are driven directly by the connecting rods. Since the upper end of a connecting rod is fitted directly to the piston (also referred to as wrist or trunk) pin, the piston tends to develop a side pressure against the cylinder walls. To distribute the side pressure over a wide area of the cylinder walls or liners, use pistons with long skirts. This type of piston minimizes cylinder wall wear. Differential pistons, as shown in view B, figure 6-39, are modified trunk pistons with two or more different diameters. These pistons are fitted into special cylinders arranged so more than one stage of compression is achieved by one piston. The compression for one stage takes place over the piston crown; compression for the other stage(s) takes place in the annular space between the large and small diameters of the piston.

Drain cocks are provided at the bottom of the compressor suction control and the engine speed control. These cocks should be left open when the unit is standing idle, particularly in freezing weather. They must be closed before starting the engine. Check the oil level in the oil storage tanks as indicated by the gauge. If necessary, add oil according to the oil specifications given in the manufacturer's lubrication manual. Drain any condensate that has accumulated in the bottom of the oil storage tanks. A drain cock is provided on the piping at the bottom of the left-hand oil storage tank. Open this cock and keep it open as long as water is draining out. Close the cock quickly when oil starts draining.

LUBRICATION SYSTEM

Except for oil-free (nonlubricated) compressors, high-pressure air compressor cylinders are generally lubricated by an adjustable force-feed lubricator

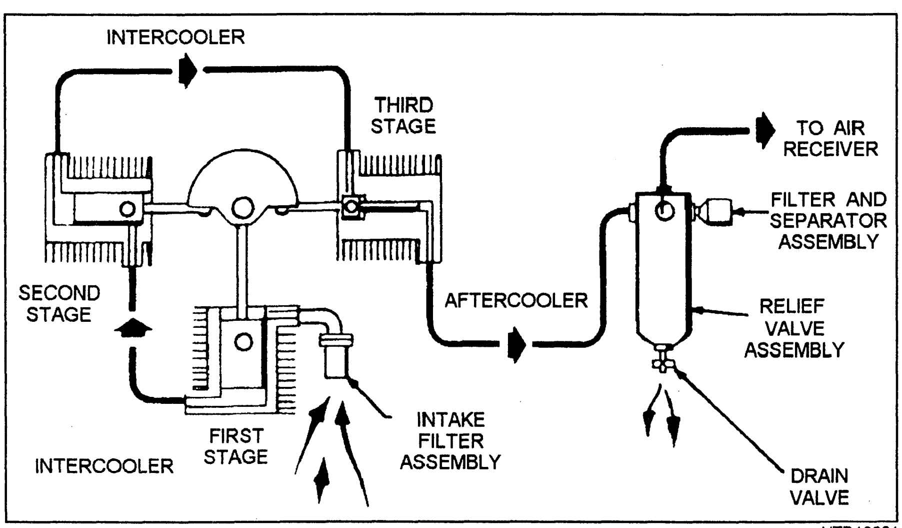

Figure 6-36.—Air compressor assembly.

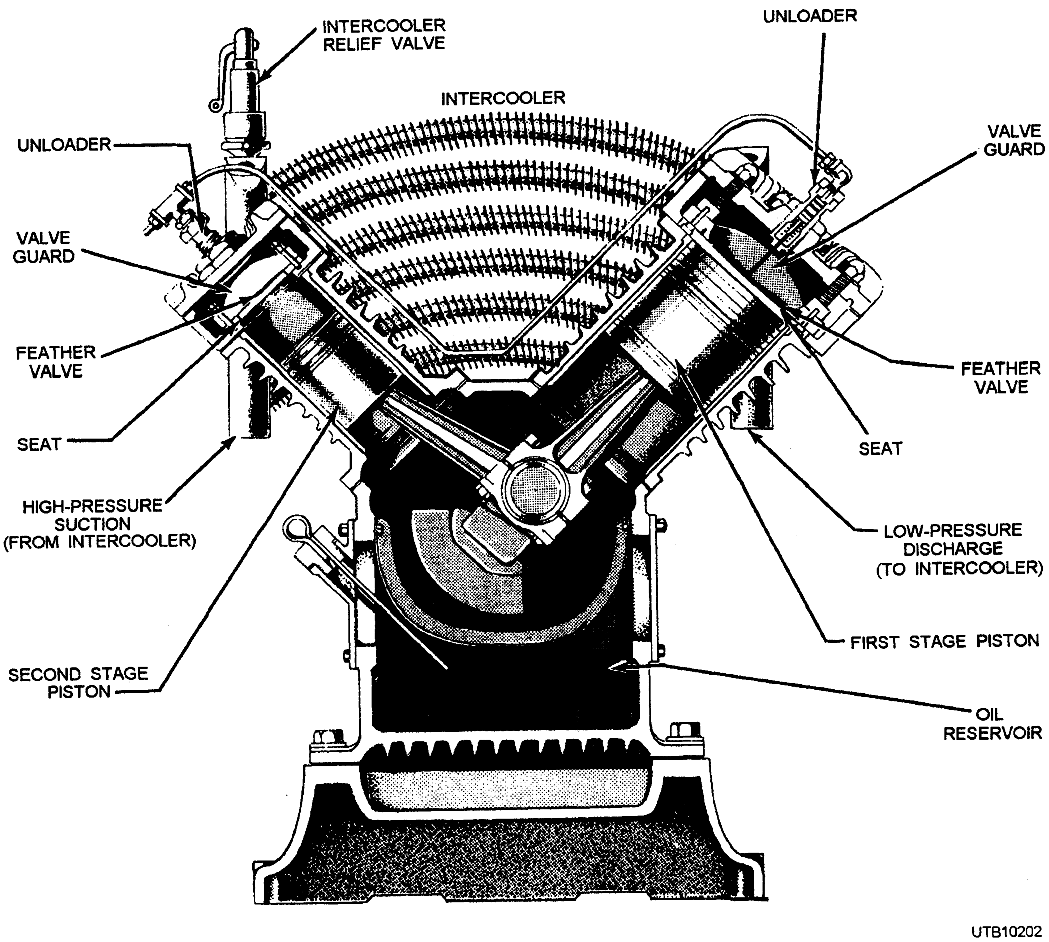

Figure 6-37.—A two-stage reciprocating air compressor.

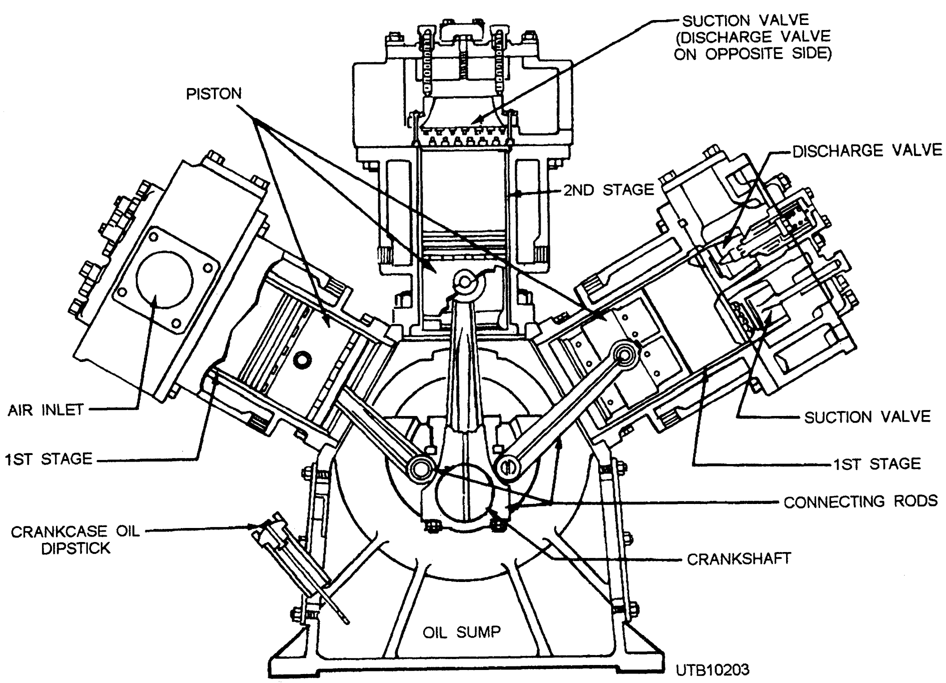

Figure 6-38.—Low-pressure reciprocating air compressor, vertical W configuration.

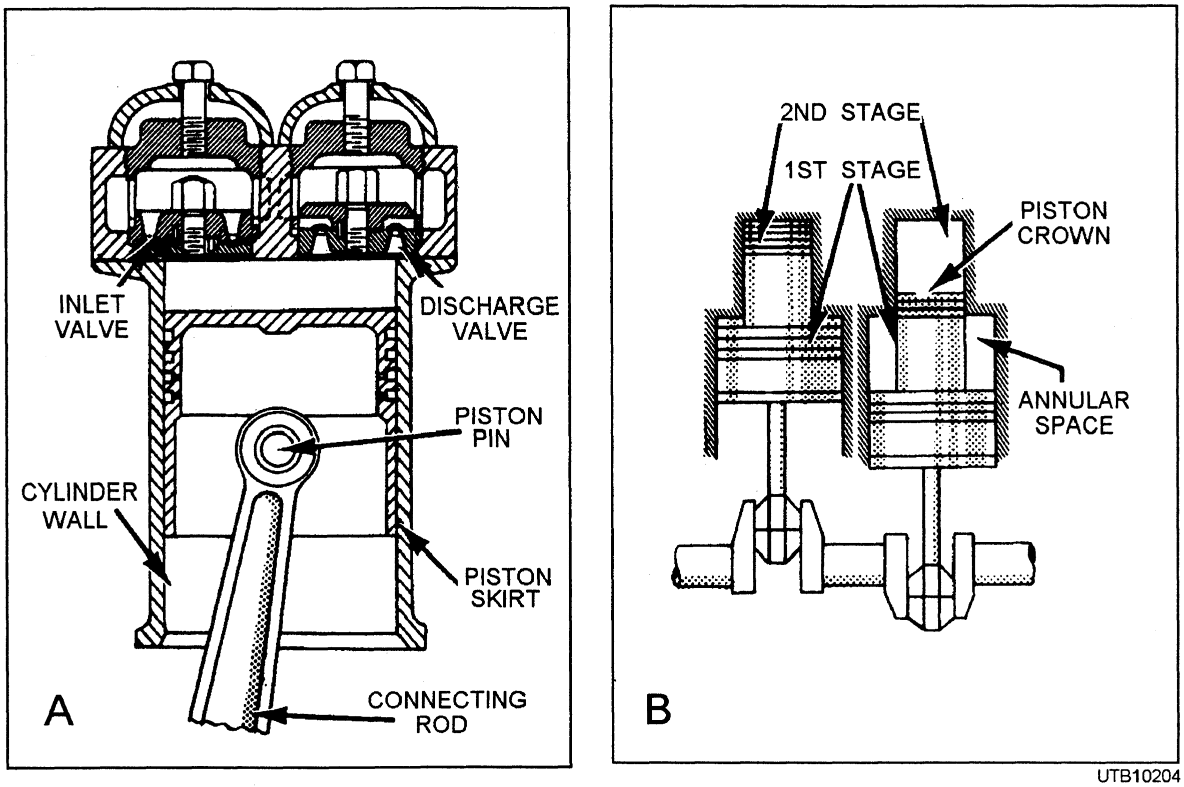

Figure 6-39.—Air compressor pistons: A. Trunk type; B. Differential type.

driven from a reciprocating or rotary part of the compressor. Oil is fed from the cylinder lubricator by separate lines to each cylinder. A check valve is installed at the end of each feed line to keep the compressed air from forcing the oil back into the lubricator. The oil is distributed to the top of each main bearing, to spring nozzles for reduction gears, and to outboard bearings. The crankshaft is drilled so oil fed to the main bearings is picked up at the main bearing journals and carried to the crank journals. The connecting rods contain passages that conduct lubricating oil from the crank bearings up to the piston pin bushings. As oil leaks out from the various bearings, it drips back into the oil sump (in the base of the compressor) and is recirculated. Oil from the outboard bearings is carried back to the stirrup by the drain lines.

Low-pressure air compressor lubrication is shown in figure 6-40. This system is similar to the running gear lubrication system or the high-pressure air compressor.

Nonlubricated reciprocating compressors have lubricated running gears (shaft and bearings) but no lubrication for the pistons and valves. This design produces oil-free air. The lubrication chart in the operator's manual for the make and model of compressor you are operating shows you where the unit should be lubricated, how often to lubricate, and what lubricant to use. The frequency depends upon operating conditions. Operating under abnormal conditions requires more frequent service.

CAUTION

BEFORE SERVICING THE COMPRESSOR AIR SYSTEM OR COMPRESSOR OIL SYSTEM, OPEN THE SERVICE VALVES TO THE ATMOSPHERE TO RELIEVE ALL PRESSURE IN THE SYSTEMS.

UNLOADING SYSTEMS

Air compressor unloading systems are installed to remove all but the friction loads on the compressors; that is, they automatically remove the compression load from the compressor while the unit is starting and automatically apply the load after the unit is up to operating speed. For units with start-stop control, the unloading system is separate from the control system. For compressors equipped with constant-speed control, the unloading and control systems are integrated. A few typical compressor unloading

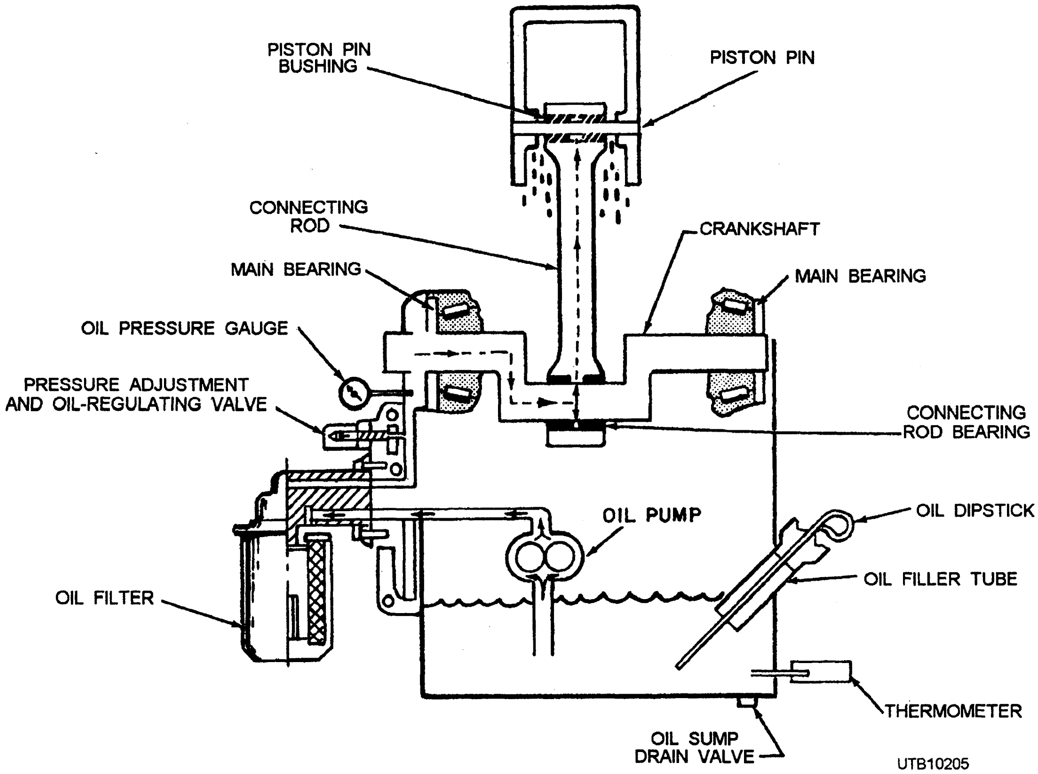

Figure 6-40.—Lubricating oil system of a low-pressure air compressor.

methods are discussed in the paragraphs that follow. These methods include the following:

- Closing or throttling the compressor intake
- Holding intake valves off their seats
- Relieving intercoolers to the atmosphere
- Relieving the final discharge to the atmosphere (or opening a bypass from the discharge to the intake)
- Opening up cylinder clearance pockets
- Using miscellaneous constant-speed unloading devices
- Combinations of the above methods

As an example of a typical compressor unloading device, consider the MAGNETIC-TYPE UNLOADER. Figure 6-41 shows the unloader valve arrangement. This unloader consists of a solenoid-operated valve connected with the motor starter. When the compressor is at rest, the solenoid valve is de-energized to admit air from the receiver to the unloading mechanism. When the compressor reaches near-normal speeds, the solenoid valve is energized to release the pressure from the unloading mechanism and to load the compressor again. For details on the unloading devices, refer to the pertinent manufacturer's technical manuals for compressors installed in your command.

Since compressors draw in ambient air, or the air surrounding the compressor, the intake is fitted with an AIR INTAKE FILTER. This filter keeps the intake air free of dust and other airborne particles. If dust-laden air enters the compressor, internal combustion, triggered by the heat of compression, can take place within the cylinders.

Moist or humid air drawn into the compressor cylinders poses another problem. The air intake filter

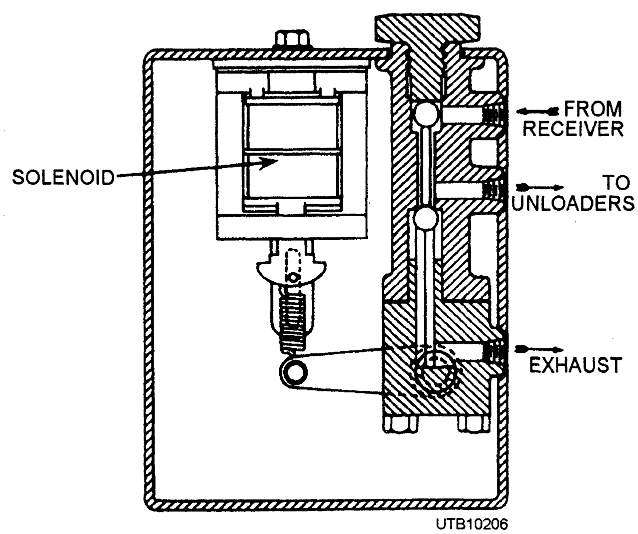

Figure 6-41.—Magnetic-type unloader.

cannot prevent this water vapor from being taken into the compressor. Instead, the water vapor is usually squeezed out of the air during compression and transformed into steam by the heat of compression. The steam condenses to form moisture droplets downstream from the compressor, as the compressed air charge is cooled. Since moisture can damage some of the machines that use compressed air (pneumatic tools, for example), the moisture must be removed from the air before it is sent to the storage tank. So, a FILTER and a MOISTURE SEPARATOR ASSEMBLY are placed between the compressor and the storage tank. The assembly removes most of the moisture, or any other impurities, entrained in the air before it is sent on to storage. The assembly is fitted with a valve or drain cock, so accumulations of water and dirt can be drained now and then by the operator.

The tank that stores the compressed air is called the AIR RECEIVER, as shown in figure 6-42. In this way, demands for compressed air are made upon the receiver, rather than directly on the compressor itself. And there is little chance of the demand for air exceeding the supply. To this end, the air receiver has with it some type of control system or device to monitor the supply of compressed air in the receiver. The control device may be a PRESSURE SWITCH that senses predetermined thresholds or levels of pressure. When the compressor has sufficiently charged the receiver with compressed air, the pressure switch automatically opens and shuts down the compressor. If and when the demand for compressed air begins to drain the receiver to a preset pressure threshold, the pressure switch closes and automatically starts the compressor.

In systems where the demand for air is more or less constant and prolonged, a type of CONSTANT-SPEED CONTROL can be used. The compressor is permitted to run continuously to keep the receiver charged with air, while the constant-speed control functions somewhat like a pressure relief valve. If the pressure of the compressed air in the receiver rises, because of a momentary drop in demand within the system, the control simply vents the excess compressed air to the atmosphere, rather than shut down the compressor.

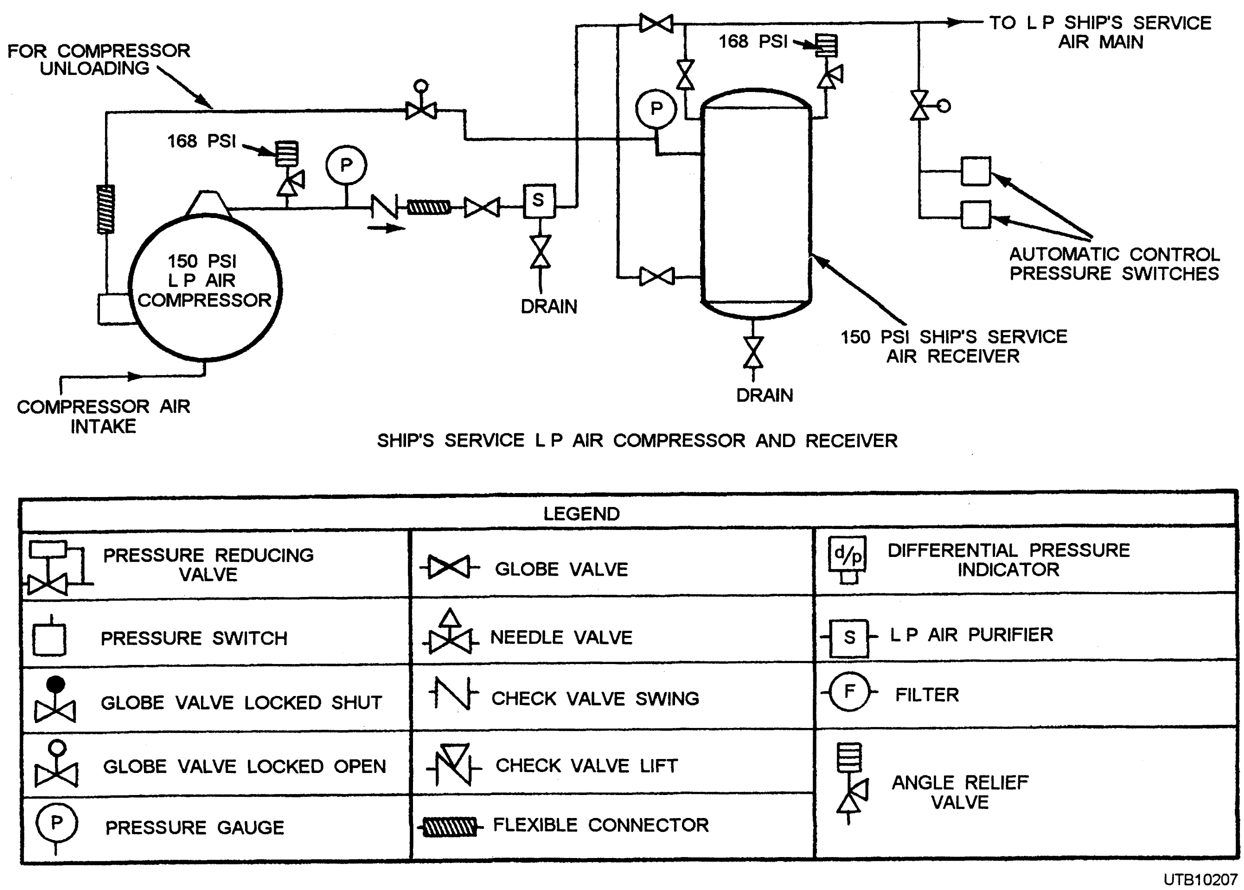

Figure 6-42.—LP air compressor piping arrangements.

COOLING SYSTEM

The generation of heat always accompanies the compression of air. In most low-pressure air compressors, the heat from compression is dissipated before the temperature gets too high. Aluminum cylinders have cooling fins, and a fan forces cooling air past the cylinders. In most medium-pressure and high-pressure air compressors, the compressor has to be cooled with pump-circulated water. The cooling water is circulated in much the same fashion as in an automobile engine with the coolant passing through jackets in the cylinder walls, cylinder heads, and so on. In addition, compressors are fitted with other cooling devices, known as intercoolers and aftercoolers. Generally, these devices consist of a series of tubes, either air-cooled or water-cooled, through which the compressed air charge flows after leaving the cylinders. These devices cool the compressed air. INTERCOOLERS are placed between the stages or cylinders of multistage compressors. Thus they cool the compressed air charge before it is drawn into the next cylinder. The AFTERCOOLERS cool the final discharge of air from the compressor. Both the intercoolers and the aftercoolers are of the same general construction, except the aftercoolers are designed to withstand a higher working pressure.

Perhaps the most important advantage of these coolers is they aid in keeping the air charge in a compressed state. In other words, hot air has a tendency to expand, and if the compressed air charge is not cooled, it, too, tends to expand and thereby liberate much of its pressure or energy.

COMPRESSOR LOCATION

Locate the compressor unit so that it is reasonably level. The design of this unit permits a 15-degree lengthwise and a 15-degree sideways limit on out-of-level operation. The engine, not the compressor, is the limiting factor. When the unit is to be operated out of level, keep the engine crankcase oil level near the high level mark (with the unit level) and have the compressor oil gauge show nearly full (with the unit level). The mechanical parking brake lever is near the bumper. Set the brake by pulling or pushing the lever as directed by a decal or a stencil located beside the lever on the unit. The parking brake should always be set once the air compressor is on location to prevent accidental rolling of the unit, which could cause not only mechanical damage but also possible injury to personnel. As an added precaution, the wheels should be chocked when possible.

Open the side curtains on both sides of the enclosure and leave them open whenever the unit is in operation. When the side curtains are closed and the engine running, the flow of air through the oil cooler and engine radiator is restricted. The curtains may be left closed for a few minutes during starting procedures in cold weather to ease engine warm-up. However, when the compressor goes to work, open the side curtains. For specific operating instructions, check the instruction plate attached to the unit being used.

ENGINE

The heart of the compressor is the engine that furnishes power for the compressor and produces air for the pneumatic tools used during drilling. Know how to start, operate, and maintain the compressor engine properly. In most cases, the general operating procedure is similar to that given below. Check the engine oil level. If necessary, add oil as recommended in the engine manual. Do not overfill.

Check the engine cooling system. The radiator should be filled to the bottom of the filler neck. If necessary, add soft, clean water until full. In cold weather, use a permanent antifreeze with a rust inhibitor. Ethylene glycol solutions are recommended because they do not evaporate and only water is added to maintain a full system. Two fuel tanks are furnished-one on each side. The two tanks are cross-connected to permit filling from either side of the unit. Clean fuel is vitally important. Ensure clean fuel is poured or pumped into the tanks. Be sure no condensate (water) lies in the bottom of the fuel tanks. Drain off any water that may be there. Clear away obstructions in the vents of the fuel tank.

Lubricate all parts of the engine as recommended in the manufacturer's engine manual. Make periodic checks of the oil filter, the fuel filter, and the fuel oil pump screen. Ensure the rain cap on the exhaust pipe swings freely,, so a back pressure on the engine exhaust cannot be created. Check the battery cells for the proper liquid level. A pair of two-stage dry-type air cleaners filters the intake air for the compressor suction and engine air-intake manifold. Both cleaners are under the canopy at the compressor end of the unit.

The first stage of the air cleaner uses centrifugal precleaning which rotates the intake air and separates a large portion of the dust collected in the dust cup. The dust cup should be checked and emptied daily.

The second stage of the air cleaner consists of a group of cylindrical pleated paper elements. The ends of the pleats are molded into a flexible plastic faceplate that seals the cartridge in place in the air cleaner housing without additional gaskets. On the side of the air cleaner housing is mounted a service indicator. As the second-stage cartridge loads up with dirt, a red indicator flag gradually rises in the window. When the cartridge is completely loaded, the window shows all red, and the flag is locked in place. This is the time to replace the second-stage cartridge. Discard the old cartridge and reset the red flag, so the window shows clear. Do not clean used paper cartridges.

OPERATION AND MAINTENANCE OF AIR COMPRESSORS

Before the compressor is started, the operator should make inspections to ensure that both the compressor and the auxiliary components are ready for operation. This procedure includes the following: checks of the control and unloading systems; inspection of safety valves or pressure relief valves; draining condensate from the coolers, the separator, and the receiver; and turning on cooling water services and opening valves to ensure proper circulation of water through the compressor and coolers.

Once the compressor is in operation, the operator must periodically check the temperature and pressure of the cooling water, the lube oil, and the compressed air. The lube oil level must also be checked and maintained at the proper level. Coolers must be inspected for correct temperature and flow of water. Accumulations of moisture in the coolers, the separator, and the air receiver must be drained periodically. In addition, maintenance schedules require more detailed inspections (monthly, quarterly, etc.). In many cases, these inspections require dismantling parts of the compressor and auxiliary equipment. For instance, the operator may be required to inspect intake and discharge valves, cylinders, and pistons. The air intake filter must be inspected periodically and cleaned as necessary. The coolers and the receiver must also be inspected for corrosion and accumulations of dirt and oil.

The lubrication system on most compressors is somewhat similar to that on an automobile engine. Normally, the compressor base is used as the lube oil sump and oil pump housing. The oil level can be measured by a dipstick or an oil level sight gauge mounted on the base. The lube oil is distributed through various passages to lubricate bearings, valves, pistons, and other internal parts. An oil film is also distributed over the cylinder walls. Although small amounts of lube oil may mix with the compressed air, it is usually filtered out at the separator assembly. Note that one of the periodic operator inspections on air-lift pumps is to check the air-water discharge from the pump for contamination by lube oil entrained in the compressed air.

The lube oil used in the cylinders must be of the right type. The auto-ignition point (temperature at which oil vapor bums without the presence of a spark or flame) of these oils must always be well above the highest heat of compression; otherwise, there is the danger of internal combustion in the compressor cylinders. An example of a Seabee operated and maintained compressor is discussed in the paragraphs below. The 600 ft3/min, portable air compressor is a single cylinder, sliding vane, oil-cooled, positive displacement rotary compressor, connected through a friction disk clutch to a heavy-duty industrial diesel engine. The complete assembly is equipped with a semi-elliptical spring mounting, pneumatic tires, and drawbar.

The portable compressor comes equipped with all components essential for proper operation, including the following:

A heavy-duty, single, dry-type air cleaner to provide clean air for the compressor and engine with a minimum of service requirements.

Large, cool radiator elements with ample capacity for efficient, dependable cooling of the compressor oil and engine coolant.

Oil filters with replaceable cartridges for efficient filtration of the compressor oil and engine crankcase oil. Automotive-type instrument panel with easy-to-read gauges and electrical instruments.

Pneumatic regulating controls that provide for economical engine operation under all loads.

A combination thermostatic valve and bypass to assure rapid warm-up and optimum compressor performance over a wide range of surrounding air temperatures.

An electrically operated shutdown system to stop the engine if a malfunction occurs in the compressor and/or engine.

A blowdown valve to relieve the pressure in the receiver and air-flow system automatically each time the engine is shut down.

An oil flow system that eliminates the need for an oil circulating pump.

COMPRESSED-AIR DISTRIBUTION

Compressed air is a powerful energy source which is very useful in military and industrial applications. It is of particular advantage in applications that require intermittent power at some distance from its source, as the air pressure can be maintained nearly constant at work intervals. The rest of this chapter will pertain to proper installation techniques of compressed-air systems. When you are assigned a project that includes compressed air lines, follow the prints and specifications.

Pressures and Uses

Compressed air usually falls into one of three categories-power service, process service, or control purposes.

Power service is when compressed air either moves something or exerts a force. Examples of power service uses are pneumatic tool operation, air lifts, clamps, and cylinders.

Process service is when compressed air is used as part of the process itself. An example is the use of compressed air in a combustion process. Compressed air provides oxygen for the combustion, and, in turn, it becomes a part of the combustion products and is no longer identifiable as air.

Control purpose is when compressed air is used to govern and/or regulate various equipment by monitoring pressure or flow rates of some substance. A pneumatically controlled combustion system is an example of such an application.

Compressed air is distributed at low, medium, or high pressure. A low-pressure system delivers air up to 125 psig. When several different pressures are required within that range, the plant is usually designed for the highest pressure. Typical low-pressure systems include the following: air motors, crane drives, starting motors for combustion engines, shops, laundry and dry-cleaning plants, and general service (tools, cleaning, painting, and soot blowing for HTW generators and steam boilers).

Medium-pressure systems deliver air from 126 to 399 psig. Normally, this type of system provides an individual compressor located near the load. Typical applications are starting diesel engines, hydraulic lifts, and retread tire molds.

High-pressure compressed air systems range from 400 to 6,000 psig. To minimize the hazard that exists with higher pressures and capacities, you can use separate compressors for each required pressure. Some applications are torpedo workshop, ammunitions depot, catapults, wind tunnel, and testing laboratories.

Piping

Distribution piping is either aboveground or underground. Both aboveground and underground piping systems have advantages and disadvantages. The advantages of each system are as follows:

Aboveground	Underground
Initial cost is lower	Less vulnerable target
Less maintenance	Less obstruction to traffic
Easy detection of failure	Less unsightly
Higher continuous operating efficiency	Freeze protected when buried
Longer life	

Some other factors considered are permanent versus temporary use, existence of high water table, annual ownership, operation and maintenance costs, and degree of hazard (example, potential danger that overhead piping may cause to aircraft operations).

Low-pressure and medium-pressure systems use black steel pipe. Preferably the joints are welded. Special conditions may require stainless steel and copper tubing with appropriate fittings. Connections to removable equipment are always flange fittings, except when using small threaded pipe.

High-pressure systems use seamless steel pipe with butt welded fittings. Screwed fittings, when used, have their ends sealed by fillet welds and exposed pipe threads covered with weld.

Piping supports are held in place by U-shaped or similar types of hangers firmly secured to support structures. Support hangers must fit closely around the pipe, but may allow for slight movement. Aboveground pipe is pitched downward a minimum of 3 inches per 100 feet of length, in the direction of the airflow, to low points where the condensate is collected and drained through drip legs. The drip legs are at all low points, bottom of all risers, and every 200 to 300 feet from horizontally pitched pipe.

Underground piping is normally placed as direct burial. Because this type of placement generally lowers the temperature of the air in the piping, more condensation will form within the pipe than in an aboveground system. The provisions to remove the condensation may be building basement drip legs, or manholes may be required. If the soil is corrosive, cathodic protection may be needed. Underground lines are pitched the same as aboveground lines at 3 inches per 100 feet; however, drip legs differ from aboveground lines in that belowground lines require a drip leg at not over 500 feet. Insulation on buried compressed air piping should be shop-coated, wrapped, tested, and handled according to the NAVFAC specification 34-Y, *Bituminous Coating for Steel Surfaces.*

Auxiliary Equipment

Air filters are provided on compressor intakes to prevent atmospheric dust from entering the compressor and causing scoring and excessive wear. Two types of air filters are used-the dry type and the oil-wetted type. Generally, the dry-type filter is more efficient than the oil-wetted type in trapping and removing very fine, solid particles from the incoming air; however, dry-type filters require cleaning and replacement more often than the oil-wetted types. Oil-wetted types are usually used under very dusty, dirty atmospheric conditions.

SILENCERS.-Air compressors are fitted with silencers (fig. 6-43) that are sound-absorbing devices attached at the intake and output of the compressor. In general, air noise silencers are cylindrical housings containing acoustically tuned baffles and sound-absorbing material.

INTERCOOLERS AND AFTERCOOLERS.— Intercoolers and aftercoolers are used to reduce the heat buildup due to the compression of air. The two mediums used are water and air. Normally air is used on smaller compressors. The air-cooled heat exchanger is simply a set of fins and/or tubular radiator. No liquid of any sort is used for cooling. The water-cooled heat exchanger operates as a shell and tube design (fig. 6-44). The tubes commonly consist of

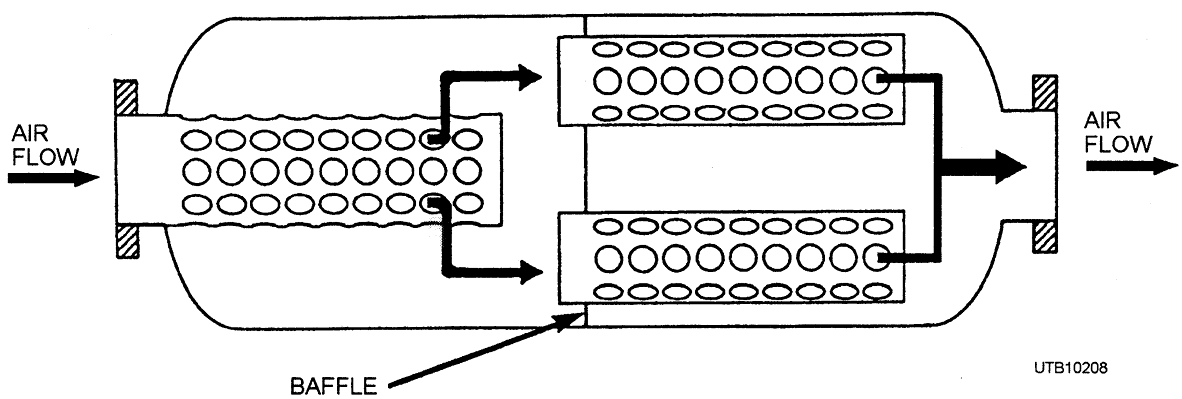

Figure 6-43.—Compressor intake silencer.

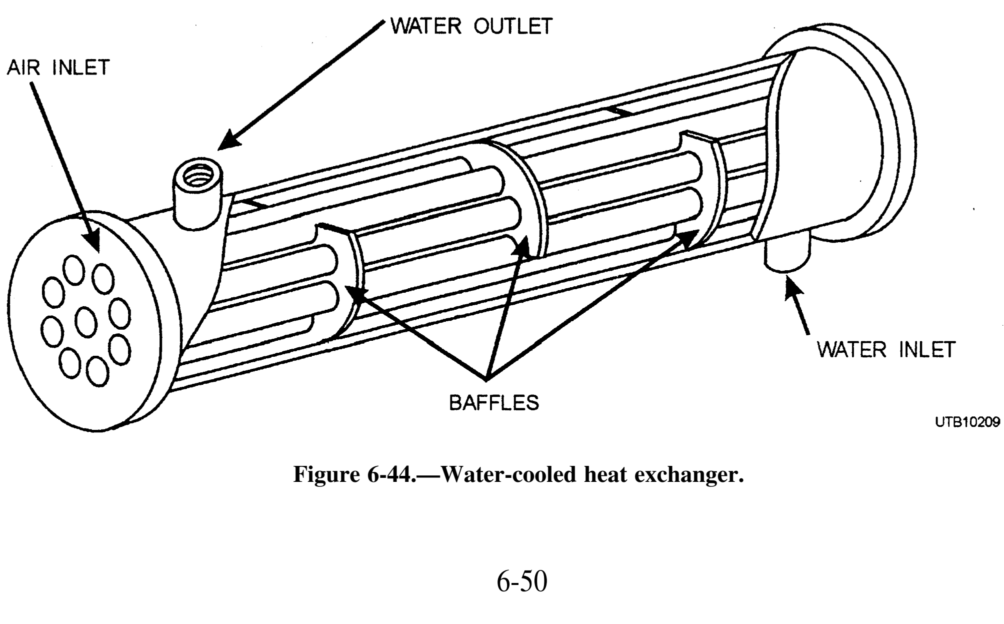

Figure 6-44.—Water-cooled heat exchanger.

a single bundle of tubes enclosed in a cylindrical shell. The air to be cooled passes through the tubes while the water circulates around the outside of the tubes absorbing the heat from' the compressed air. The baffles are used to direct the water flow across the heat exchanger tubes in the most efficient manner. The intercooler is located between the discharge of one cylinder and the intake of the next cylinder on a multistage compressor. The intercooler reduces the temperature and volume of the compressed air for delivery to the next compression stage. The aftercooler is located at the discharge of the last cylinder to cool the air, to reduce the volume, and to liquify any condensable vapors.

SEPARATORS.—Separators remove oil and water from compressed air. Figure 6-45 shows a centrifugal moisture separator. The air enters the unit in a swir ling motion. Centrifugal action forces the moisture to the walls of the separator and then the moisture drains to the bottom of the separator.

Another type of separator is the baffle type. This separator causes the air entering the separator to make sudden changes in direction, causing the heavier moisture particles to strike the baffles and walls and drain to the bottom.

TRAPS.—Compressor plant traps drain moisture from intercoolers, aftercoolers, receivers, and distribution piping. Common traps used are the ball float, the bucket, and the inverted bucket traps (fig. 6-46).

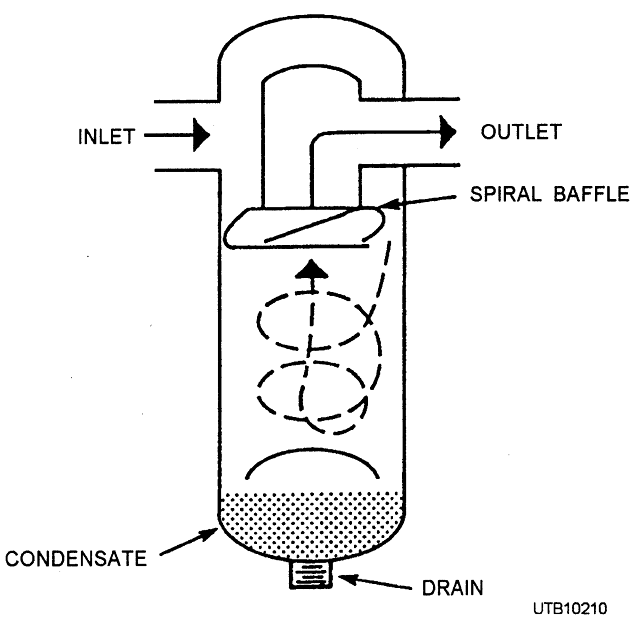

Figure 6-45.—Centrifugal moisture separator.

AIR RECEIVERS.—The receiver is nothing more than a tank designed to hold the -air that is compressed to meet supply peak demands that are in excess of the compressor capacity. Additionally, receivers function as pulsation dampers on reciprocating compressor installations. Figure 6-47 shows an air receiver.

DRYERS.—Dryers remove moisture from compressed air that would condense in air lines, air tools, and pneumatic instruments. Condensation can cause damage to equipment by corrosion, freezing, and water hammer, and will cause instruments to malfunction. The three types of dryers are adsorption, deliquescent, and refrigeration.

The adsorptive dryer is made of some type of desiccant, such as silica gel or activated alumina. The desiccant adsorbs and holds the water vapor from the air. Adsorption-type dryers (fig. 6-48) consist of two drying towers, each containing an adsorbent, plumed in parallel. The drying towers are cycled manually or automatically, so one tower is on stream and the other tower is being reactivated. Reactivation is accomplished by heating the desiccant which drives the moisture out to waste.

Only one type of dryer was discussed in this chapter. Other types of dryers, maintenance, operation of controls, and other interesting information about compressors can be found in NAVFAC MO-206, *Maintenance and Operation of Compressor Plants.*

SAFETY PRECAUTIONS

Listed below are some safety tips on how you can avoid air compressor accidents.

- Keep the hose connections on portable air compressors tight, and inspect these connections often to ensure they remain tight.
- Check the safety valves and gauges frequently to make sure they are working correctly.
- Use fixed tow bars, not chains or ropes, when moving portable air compressors.
- Check the wheels of portable air compressor carriages to ensure proper operation.
- When an air compressor is started, check the safety valves, the pressure controls, and the regulators to determine that they are working properly.
- DO NOT leave the area of an operating compressor unless you are sure that the control,

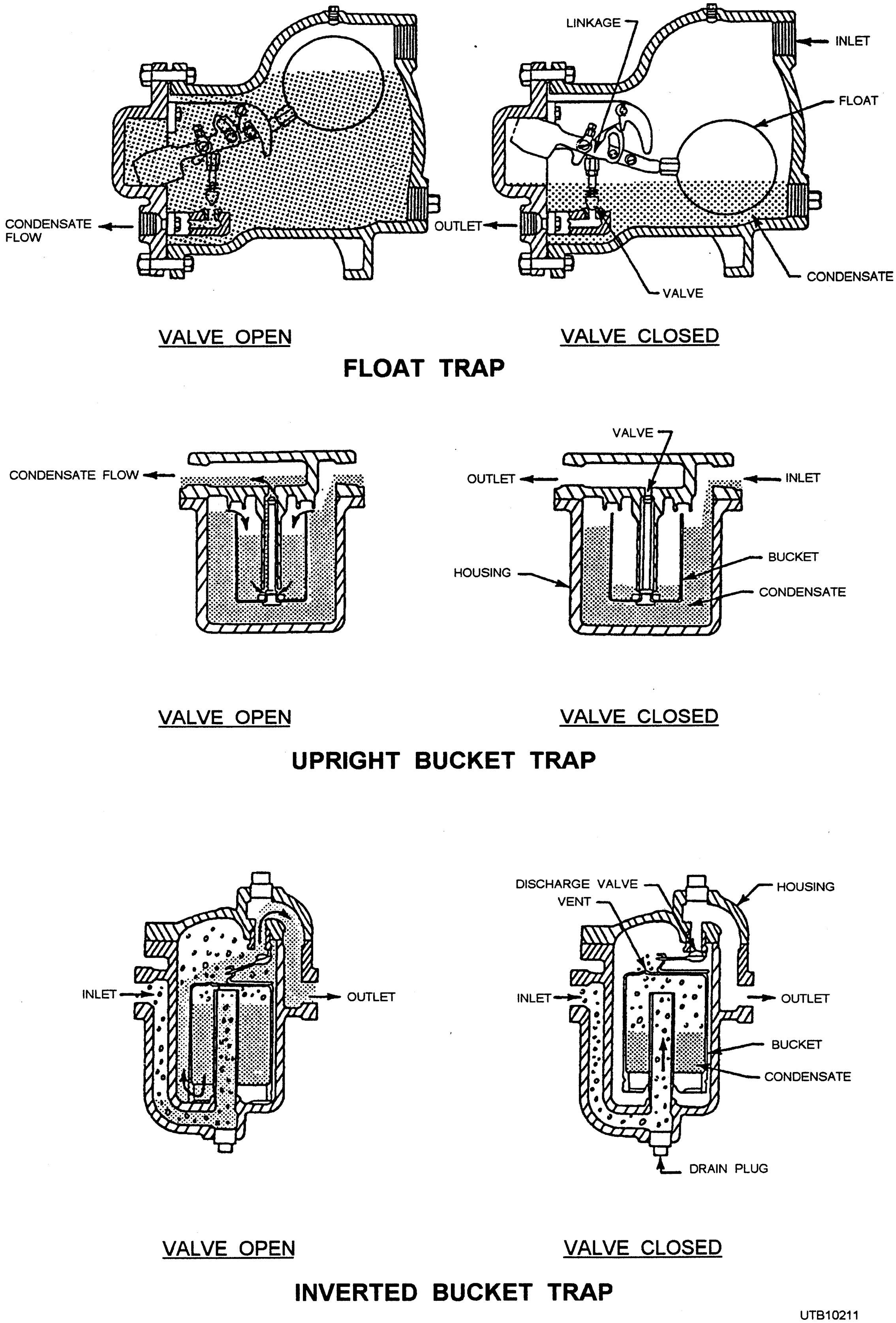

Figure 6-46.—Traps: A. Float; B. Upright bucket; C. Inverted bucket.

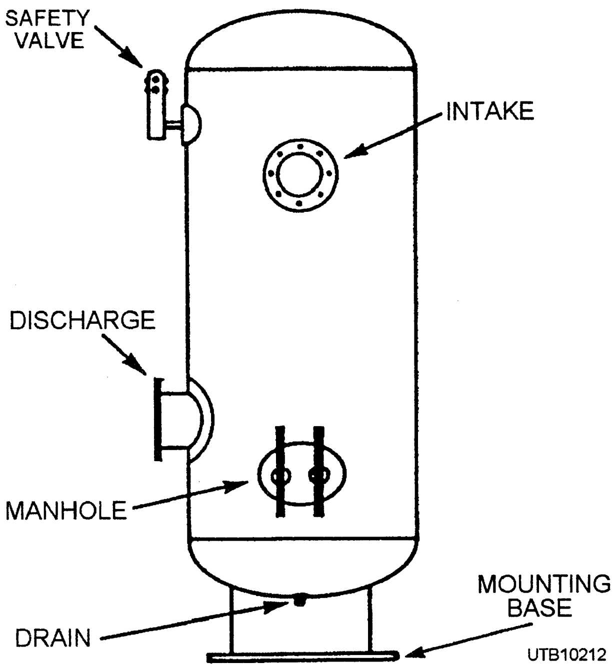

Figure 6-47.—Air receiver.

the unloading, and the governing devices are working properly.

- Do NOT run a compressor faster than the speed recommended by the manufacturer.
- Be sure that air at the compressor intake is cool and free from flammable gases, vapors, and dust.
- Do NOT permit wood or other flammable material to remain in contact with the air discharge pipe.
- Immediately secure a compressor when the temperature of the air discharge from any stage rises unduly or exceeds 400°F.
- Do NOT install a check valve or drop valve between the compressor and receiver unless a relief valve is also fitted between the compressor and the stop or check valve. (If the compressor is started against a closed valve or defective check valve, an explosion can result.)
- Pressure gauges must be in working order unless you have to remove them for repair.
- NEVER kink a hose to stop the air flow, and always keep clamps on the hose tight.
- Keep compressor pipes and tanks clean to guard against an oil vapor explosion. Clean intake air filters periodically.
- Turn off the motor before adjusting and repairing an air compressor.
- Use only soapy water or another suitable nontoxic, nonflammable solution for cleaning compression intake filters, cylinders, or air passages. NEVER use benzene, kerosene, or other light oils to clean these portions of a system. These oils vaporize easily and form a highly explosive mixture under compression.
- Know what compressors can do, realize they are dangerous, and then use them safely

Q22. What are the three types of air compressors?

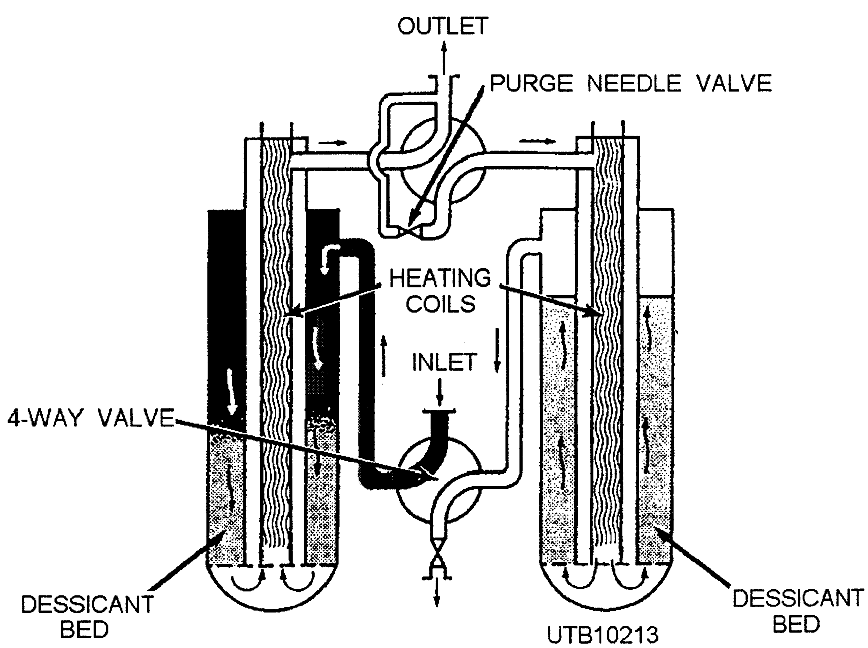

Figure 6-48.—Flow diagram of an electric adsorption dryer.

Q23. What type of prime mover drives the majority of air compressors used in the Navy?

Q24. What is the one type of load that unloading systems on air compressors cannot remove?

Q25. What is the purpose of an after cooler?

Q24. What auxiliary equipment on an air compressor removes moisture from the system?